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Cutting and environmental effects on growth and regrowth of a sorghum-sudangrass hybrid, cultivar sudax sx-11

James Edward Beuerlein

To the Graduate Council:

I am submitting herewith a thesis written by James Edward Beuerlein entitled "Cutting and environmental effects on growth and regrowth of a sorghum-sudangrass hybrid, cultivar sudax sx-11." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Henry A. Fribourg, Major Professor

We have read this thesis and recommend its acceptance:

Frank F Bell, Curtis F. Lard

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 30, 1967

To the Graduate Council:

I am submitting herewith a thesis written by James Edward Beuerlein entitled "Cutting and Environmental Effects on Growth and Regrowth of a Sorghum-Sudangrass Hybrid, Cultivar Sudax SX-11." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Henry H. Fribourg

Major Professor

We have read this thesis and recommend its acceptance:

Frank F. Bell

Curtis L. Laird

Accepted for the Council:

Hilton A. Smith

Vice President for
Graduate Studies and Research

CUTTING AND ENVIRONMENTAL EFFECTS ON GROWTH AND REGROWTH OF A SORGHUM-SUDANGRASS HYBRID, CULTIVAR SUDAX SX-11

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

James Edward Beuerlein

August 1967

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

Summer annual forages are an important part of the forage program of beef and dairy farmers in Tennessee. In 1966, approximately 140,000 acres of sudangrasses, pearlmillets, and sorghum-sudangrass hybrids in pure stand were grown in Tennessee. This was an increase of 100 per cent from 1961 when only 70,000 acres of the crops were grown. When used as a supplemental forage, the sorghum-sudangrass hybrids help maintain a high level of production during the summer months when unfavorable climatic conditions often bring about a decrease in production and quality of perennial forage.

Although sorghum-sudangrass hybrids are accepted and widely used by farmers, very little is known about their growth and regrowth after harvesting. In order to maximize yields and profits the farmer must know when to harvest a crop for the most suitable combination of yield and quality. The expected amount and the rate of dry matter production after one or more harvests is of vital importance.

An experiment was conducted to determine the effects of environment and cutting management on the growth rates and regrowth rates after harvest of a sorghum-sudangrass hybrid. Dry matter production curves were constructed for different combinations of planting date and number of harvest. An attempt was made to relate the dry matter production to plant morphological characteristics such as stem-leaf ratio and height of apical meristem, as well as several environmental factors. Statistics and graphical techniques were used to illustrate the relationships.

CHAPTER II

REVIEW OF LITERATURE

I. ADAPTATION

Sudangrass and other grass sorghums are adapted to almost every state in the United States (19). The wide-spread acceptance was cited by Carter (10), who reported in 1954 that there were ten million acres of sudangrass grown annually in the United States. Baylor (2) reported that some of the summer annuals will produce more total digestible nutrients per acre than many of the perennial grasses. According to Dawson *et al.* (13), sudangrass is able to produce high quality forage in July, August, and September because of its drought and heat resistance.

In the 1950's work was begun on developing a hybrid between sorghum (*Sorghum vulgare* Pers.) and sudangrass (*S. sudanense* (cv. Piper) Stepf.). Cragmiles *et al.* (12) reported that F_1 hybrids of sorghum and sudangrass would yield approximately one ton per acre more than either parent. The increase in yield was hypothesized to be due to heterosis. In 1958, F_1 hybrids of sorghum and sudangrass became available and various workers reported results similar to those obtained by Craigmiles *et al.* (12). Baylor (1) stated that sorghum-sudangrass hybrids might be expected to yield two tons more dry matter per acre than sudangrass. Research in Pennsylvania by Harrington and Washko (21) indicated that sorghum-sudangrass hybrids produced 1.5 tons more dry matter than did Piper sudangrass. In Australia, Boyle and McDonald (7) found that a sorghum-sudangrass hybrid variety, Sudax SX-11, was superior to all other sorghums grown in their experiment. In 1964, Pardee (28) reported that farmers and researchers were recognizing the potentials of sorghum-sudangrass hybrids for pasture and green-chop.

II. THE EFFECT OF CUTTING MANAGEMENT ON QUALITY

The literature on the effect of cutting management on the quality of a sudangrass-sorghum hybrid is extremely limited, but there is some information regarding the effect of cutting management on the quality of sudangrasses and millets.

One needs only to take a brief look at the literature to see that there are many definitions of quality. Quality has been expressed as: stem-leaf ratio, per cent crude fiber, per cent soluble solids, per cent nitrogen-free extract, per cent digestible nutrients, and as digestibility coefficients. It is beyond the scope of this text to define the term quality as it is used to qualify or quantify the desirability of forage material.

Browning _et al_. (8) reported that dairy cows grazing Sudax SX-11 produced 4058 pounds of 4 per cent fat-corrected milk (FCM) per acre, while dairy cows grazing Greenleaf sudangrass produced 3810 pounds of 4 per cent FCM per acre. Stillcup and Davis (32) found that the total digestible nutrient values and the coefficients of digestible protein of sorghum-sudangrass hybrids were comparable to those obtained from high quality sudangrass.

Morrison (26) reported that sorghum forage was nutritious and palatable and provided at least 90 per cent of the feeding value of corn. Carter (11) found that sorghum in the dough to hard-seed stage averaged about 7 per cent at Fargo, North Dakota, from 1952 to 1957, and had about the same protein content as corn.

Koller and Clark (24) observed that, under a pasture management system, the forage quality of sudangrass at the initial harvest decreased as stand density was increased. Due to depression of regrowth in dense stands following the first harvest, forage quality was higher for the greater stand densities of the second harvest.

Rusoff et al. (31) have shown that the lignin content of Starr pearlmillet increased progressively from 3.23 per cent to 6.72 per cent from the first to the fifth cutting, and crude protein decreased from 13.1 per cent to 5.9 per cent over the same clipping range.

Van Keuren and Pratt (40) noted, in digestion trials conducted with lactating dairy cows, that Piper sudangrass at 30 to 36 inches in height, when fed as green-chop on July 6-10, had a dry matter digestibility coefficient of 60.5 per cent. An alfalfa-bromegrass mixture fed on May 25-29 at the early bud stage of growth of alfalfa had a digestibility coefficient of 71.6 per cent, but by the first week in June the digestibility had declined to 63.0 per cent.

Hoveland and McCloud (23) reported maximum yields of Starr pearlmillet were obtained when plants 54 inches high were cut to a 4-inch stubble. However, such forages were low in protein. They concluded that the best combination of production and quality was obtained when 30-inch plants were clipped to an 18-inch stubble.

Dennis et al. (14) showed in Michigan that Piper sudangrass cut at 1-, 2-, 4-, and 6-week intervals produced about the same amount of crude protein in 1956, whereas plots cut at 4- and 6-week intervals in 1957 produced much more forage and nearly twice as much protein as did those cut weekly or biweekly.

Dudley (15) noted a definite livestock preference for some of the hybrids. He felt that the true value of the sorghum-sudangrass hybrids, as is the case with other forage crops, should be determined by livestock acceptance, along with other characteristics. He further stated that hybrids produced 28 per cent more air-dry forage for the season than did sudangrass varieties and were comparable in regrowth after harvest as well as in their crude protein content.

Webster (41) reported that the protein content of sudangrass-sorghum hybrids decreased as the crop approached maturity. The per cent protein in the hybrids was 1 to 2 per cent higher than in the sudangrass varieties. Protein levels of material from the first two harvests were significantly higher in plots of RS303F which set seed than in those which were sterile. The grain portion of the plants with seed accounted for 40 to 47 per cent of the total protein content. Dry matter in the forage was about 20 per cent at first bloom and nearly 30 per cent when the grain was mature.

It was noted also that in a season when environmental conditions favored continued growth, the value per acre of sorghum was greatest if harvesting for silage was delayed until after the grain was well matured.

Robinson *et al.* (30) noted in Nevada that sudangrass cut at the pre-bloom stage was a succulent green-chop forage which was readily accepted by livestock. The hay from sudangrass was comparable with other grasses but was lower in feed value than alfalfa hay. When sudangrass was cut at the early bloom stage it was higher in protein and feeding value than when cut at a later stage of growth. Sudangrass silage had about 90 per cent of the feeding value of corn silage.

III. THE EFFECT OF CUTTING MANAGEMENT ON PRODUCTION

Dennis *et al.* (14) in Michigan studied the growth response of alfalfa and sudangrass in relation to cutting practices and soil moisture. They noted that the yield of sudangrass was associated with the cutting interval--the more often the plants were cut the less productive they were.

Peters (29) reported in Nebraska that forage yields of sudangrass were affected by distance between rows and frequency of clipping. The greatest difference in yield was apparent at the first harvest and the least difference at the second harvest. A more rapid recovery was made by plants in the 40-inch row spacing after the second harvest than from the 12-inch row spacing. There was a slightly higher dry matter content of plants in the 12-inch row spacing than from the wider row spacing.

Broyles and Fribourg (9) reported that the growth of pearlmillet was more rapid from 6- and 8-inch stubble than from 3- and 4-inch stubbles. In their work, increased defoliation tended to decrease tiller production.

Beaty *et al.* (3) investigated the effect of cutting height and frequency on production of summer annual forages. The research was conducted on a Cecil sandy loam at the University of Georgia Agronomy Farm near Athens during the summers of 1961, 1962, and 1963. Tift sudangrass, Gahi-1 pearlmillet, and Sudax SX-11 were the whole plots. Split plots were harvested at 2-, 3-, 4-, or 5-week intervals, and split-split treatments were removal of 1/3, 1/2, 3/4, or 7/8 of existing plant height. They reported the following results: (1) annual yields of dry matter averaged 8446, 2399, and 6448 pounds for 1961, 1962, and 1963, respectively; (2) forage production tended to increase as harvest frequency was extended from 2 to 5 weeks; the 5-week harvest producing 46 per cent more forage than the 2-week harvest; (3) the optimum frequency of clipping depended on whether quality or quantity was the primary objective. If a high quality forage was desired, a 2- or 3-week clipping frequency combined with a 1/3 removal was preferred, whereas a 5-week frequency combined with a 3/4 or 7/8 removal gave highest yields.

IV. THE EFFECT OF ENVIRONMENT ON PRODUCTION

Bennet *et al.* (5) conducted an experiment at Thorsby, Alabama, during the 1956, 1957, and 1958 growing seasons, with three forage species grown under three moisture regimes. The species were sweet sudangrass (*Sorghum vulgare* cv. sudanense), Starr pearlmillet (*Pennisetum typhoides* (Burm.) S. & H.), and Sart sorghum (*Sorghum vulgare* cv. Sart).

The three moisture regimes were established as follows: M_1 received rainfall only, M_2 and M_3 were irrigated to field capacity when 65 and 35 per cent, respectively, of the available moisture was removed from the top 24 inches of the soil profile.

Yields of each species increased as available moisture increased, with Sart sorghum producing the highest yields at all three moisture regimes. Three-year average yields of dry matter for sweet sudangrass, Starr pearlmillet, and Sart sorghum were as follows: M_1 = 4.0, 6.0, and 9.0 tons per acre; M_2 = 5.3, 8.6, and 12.9 tons per acre; M_3 = 6.1, 10.8, and 13.8 tons per acre, respectively. The maximum green weight yields, based on the three-year average weights, were 25.3, 49.1, and 50.0 tons per acre of Sweet sudangrass, Starr pearlmillet and Sart sorghum, respectively, at the M_3 moisture regime. Sart sorghum produced 46.9 tons per acre at the M_2 regime. Water was used by the plants in proportion to the amount available for evapotranspiration were higher for the first planting than for the second, with daily rates for M_3, M_2, and M_1, respectively, being 0.22, 0.20, and 0.17 inch per day in July, and 0.16, 0.12, and 0.10 inch per day in September.

Stoffer and Van Riper (33) initiated a study to evaluate the response of sorghum to soil temperature. In the experiment, soil moisture was determined daily, but no effort was made to maintain specific levels. Two sorthum hybrids, RS610 and RS608, and another sorghum variety, Martin, were planted at the University of Nebraska Agronomy Farm at Lincoln on a Sharpsburg silty clay loam. Daily minimum soil temperatures were determined at sunrise using thermocouples. Four treatments were seeded when the minimum soil temperature at the 4-inch depth averaged 49, 55, 65, and 70 F. Available soil moisture was measured daily by means of Bouyoucos moisture blocks placed 2 inches below the soil surface. The available soil moisture was maintained above 50 per cent throughout the growing season by means of sprinkler irrigation whenever natural precipitation was low.

In an additional controlled environment study, four moisture levels of 100, 75, 50, and 25 per cent availability of water, and four temperature levels of 80, 70, 60, and 50 F. for each of the moisture levels were established. The temperature was kept constant with the use of growth chambers, and soil moisture was maintained at the original level by weighing each unit and bringing it back to its original level weight by the addition of distilled water every two days.

Results of the two studies showed that the per cent emergence in the field increased with the later planting dates until the minimum 4-inch soil temperature was 65 F. Under controlled conditions, emergence was more rapid when soil temperature increased from 50 to 65 F., but emergence did not increase as temperatures increased from 70 to 80 F. A comparison of both studies indicated the highest per cent emergence occurred at 65 F. The time of emergence was not increased by soil moisture above 50 per cent availability, since responses were not significantly different among the 50, 75, and 100 per cent moisture levels in the controlled study.

Dry matter accumulation of plants in the field was affected by precipitation as well as by soil temperature. Dry weights were lowest in plants from treatments I (low temperature) and III (low precipitation). Dry matter accumulation increased as temperature and moisture increased in the controlled study.

Taylor (36) stated that the mean soil moisture tension has been related to yields of alfalfa, sugar beets, and potatoes. His work showed that over the entire plant-growing range of soil moisture the yield was reduced as mean tension increased.

Sullivan (34) noted, in his growth chamber studies, that higher yields of dry matter were obtained at temperatures of 80 and 90 F. than at 70 F. The lignin percentages of the dry matter were greater at temperatures above 70 F. Conversely, the per cent crude protein was less at temperatures above 70 F. Average plant phosphorus percentages were lower at 80 F. than at 70 or 90 F. Total accumulation of plant phosphorus was 2.4 times greater at 80 than at 70 F.

Begg (4) reported that a crop of bulrush millet (*Pennisetum typhoides* (S. & H.)) in Canberra, Australia had a maximum growth rate of 44 ± 4 grams of dry matter per square meter per day during the ninth week after emergence. General flowering occurred during the thirteenth week after emergence and the crop had produced 21,735 kilograms of dry matter per hectare by the sixteenth week. The apical meristem height curve generally followed that of dry matter production with divergence of the two curves increasing toward the end of the sixteenth week of the growing period. At that time the apical meristem height curves were generally smooth and had a rather constant slope from the fifth through the fifteenth week after emergence.

V. ENVIRONMENT AND PHYSIOLOGY

Dennis et al. (14) observed that the amount of water used per unit of forage produced decreased as the length of the cutting interval increased. Most of the water used by sudangrass came from the upper foot of soil. During the period of active growth, daily consumption of water was closely associated with rainfall.

A number of studies have been conducted relating evaporation from a cropped surface to micrometeorological variables such as net radiation, air temperature, vapor pressure, and wind speed (17, 35, 39). The reports indicated that the stage of development of a crop affected its water loss, even after a complete crop cover was developed and while the crop was well supplied with water.

Fritschen and Van Bavel (18) found that seedheads from a somewhat mature sorghum crop absorbed radiant energy, converted it to sensible heat, and also provided a very effective aerodynamic barrier against the transfer of sensible heat to the transpiring surfaces. Evapotranspiration from the sudangrass increased with an increase in wind speed, notably during the dark periods. They concluded that for well watered sudangrass, meteorological factors, rather than physiological factors, regulated the evapotranspiration.

El-Sharkawy and Hasketh (16) initiated studies on the effect of temperature and water deficit on photosynthetic rates of different species. They used the leaf chamber technique described by Hasketh and Moss (22). The four species used in their study were Sorghum (_Sorghum vulgare_ L. 'Hegari'); Russian Sunflower (_Helianthus annis_ L.); Deltapine Smoothleaf cotton (_Gossypium hirsutum_ L.); and (_Thespesia populnea_ (L.) Soland). They stated that for these four unrelated species, leaf net photosynthetic rates were depressed by high water deficits and high temperatures. At high temperatures the leaves were turgid and the stomates were fully open; therefore, it was doubtful that transpiration was decreased when photosynthesis was depressed. The temperature optima for photosynthesis occurred at higher temperatures for leaves with the greater maximum photosynthetic rates. Except for sorghum, leaves were visibly wilted before photosynthesis was depressed by water deficit; in fact, some wilting leaves still had maximum rates. In intense light, stomatal area was limiting for sorghum and for cotton with high net photosynthetic rates.

Nakayama and Van Bavel (27) used radiophosphorus to determine the relative root activity of sorghum. They used the injection technique developed by Hall _et al._ (20). This method allowed them to follow the root activity of individual plants or groups of plants throughout their entire growing cycle. The work was conducted on a Laveen loam at the University of Arizona Experiment Farm at Mesa, Arizona. Sorghum RS610 was planted in a 40-inch row spacing, with 5 inches between plants. Radioactive injections were made at soil depths of 6, 12, 18, 24, 36, and 48 inches and at lateral distances of 5, 10, 15, and 20 inches from the row. A bi-weekly irrigation schedule consisting of approximately 4 inches of water per irrigation was used.

It was concluded that 90 per cent of the root activity occurred in the region 36 inches deep and 15 inches laterally from the plant. Roots grew at a rate of 0.75 to 2.0 inches per day.

In a similar experiment the following year they used four treatments: (1) no irrigation; (2) one irrigation when the moisture content at the two-foot depth reached 0.23 volume fraction (1 bar tension); (3) irrigation whenever the moisture content at the two-foot depth reached 0.23 volume fraction; and (4) bi-weekly irrigations. They concluded from the two experiments that approximately 90 per cent of the root activity in all treatments was confined to a zone 36 inches in depth and 10 inches wide on each side of the plant row. Total root extension was 30 inches on each side of the row and at least 60 inches deep. Rate of root growth was 1 to 2 inches per day. Moisture depletion in the 5-foot profile within the 12-week sampling period was 3.5, 4.6, 2.6, and 3.0 inches for treatments 1, 2, 3, and 4, respectively.

Blaney and Harris (6) reported that an average consumptive water use for sorghum grown in Arizona was 20 inches. There were 16.0 inches of water in the 5-foot profile at the time of planting.

McClure and Harvey (25) noted, with the use of radiophosphorus, that from emergence through the fifth week after planting, varieties varied slightly in the amount of root activity. After the fifth week, all sorghums had extended their roots approximately 45 inches downward and 22 inches laterally. Some hybrids showed a marked increase in activity during the period between flowering and maturity.

Van Bavel (38) felt that a transpiring plant cover could, for purposes of analysis, be compared to an open water surface. However, unlike evaporation from open water, transpiration could be limited by the availability of soil water and by the impedance of vapor diffusion in the leaf interstitial and stomatal pathways.

He found that transpiration from a well-watered sudangrass stand in a highly evaporative environment could be increased considerably by exposing a small plot of about one square meter to a radiative and convective heat input. Thus, the transpiration of sudangrass in a full stand appeared not to be determined by any physiological factor during any time of the day.

Tew et al. (37) noted that under a variety of transpiring conditions, lessened water uptake from the soil may limit the transpiration rate at low soil temperatures. At high soil temperatures, however, some other factors, such as the conversion of water to vapor in the leaf may have been limiting. He noted that transpiration was greater at a soil temperature of 40 C. than at 25 C. because the leaf and stem were warmer than the air. This indicated an extra source of heat. With 25 C. soil, the leaf was cooler than the air, presumably as a result of transpiration.

Whiteman (42) noted that sorghums rapidly reduced their water loss at the onset of water stress, by leaf folding and rolling. This was followed by movement of water and nutrients out of the leaf tissue, inducing progressive leaf dessication, and causing further reduction in functional leaf area. The wilting process led to drought-induced dormancy in which water loss was reduced to a minimum, meristems were being maintained, and sorghums were capable of surviving protracted drought periods.

CHAPTER III

MATERIALS AND METHODS

An experiment to ascertain the effects of certain factors of the environment, time elapsed since seeding, cutting management, and stage of growth on the growth and regrowth rates, and the distribution of dry matter over time of a sudangrass-sorghum hybrid cultivar (DeKalb Sudax SX-11) was conducted in 1966 at the Plant Science Farm, Knoxville, Tennessee.

I. EXPERIMENTAL DESIGN

A modified split-split-plot factorial design with three replications of the main treatments was used. The two main treatments were planting dates, May 10 and June 20. The split-plot treatments consisted of sets of from 6 to 13 plots per main plot. One split-plot treatment was left uncut from seeding to maturity; the others were cut uniformly and simultaneously either 1, 2, 3, or 4 times, whenever growth reached a height of 75 cm. A stubble of 15 cm. was left after each uniform cut. The split-split-plot treatments consisted of units harvested each successive week after the preceding split-plot uniform cutting treatment. A split-split-plot consisted of three rows, 92 cm. apart and 3.05 m. long; the center 2.45 m. of the center row were harvested for yield and the two outside rows served as guard rows. Each main plot measured 40 x 27.5 m. for the first planting date and 40 x 19.25 m. for the second planting date.

II. SEEDING AND FERTILIZATION

The experiment was seeded at a rate of 33.65 kg./ha., with rows oriented in an east-west direction. The experiment was grown on a Sequatchie loam. Soil test of the area indicated 15.7 and 168.0 kg./ha. of available phosphorus and potassium, respectively, before any fertilizer was applied. The whole experimental area was disk-plowed on April 4. Phosphorus at a rate of 49.5 kg./ha. and 93.5 kg./ha. of potassium were broadcast and incorporated by disking just prior to the first planting. The plots of both planting dates received 67.3 kg./ha. of nitrogen about one week after emergence and an additional 33.6 kg./ha. of nitrogen after the second and fourth uniform cuts.

When plants of the first planting date were 5 to 8 cm. tall, a severe hail storm destroyed the entire above-ground portion of the plants. The meristematic tissue was below ground level due to cultivation two days prior to the storm. The stand was not decreased to any noticeable extent. However, it was about 10 days before the plants reached again a height of 5 to 8 cm. The first plots were harvested when plants were 15 to 20 cm. tall, which was 29 days after emergence, instead of the one-week interval that had been planned. All subsequent harvests of the first planting date plots, and all harvests for the second planting date plots were done at weekly intervals.

III. CULTIVATION

Plots were kept reasonably free from weeds by cultivation, using a light-weight tractor equipped with duck-foot cultivators set at a depth of 5 cm. All plots of planting date one were cultivated three times, and those of the second planting date were cultivated twice. At the end of the growing season there was little weed infestation in the experimental plots.

IV. ENVIRONMENTAL DATA COLLECTION AND USE

A Cotton Region shelter with maximum and minimum thermometers was placed within the experimental area. In addition, a Palmer maximum-minimum dial soil thermometer was used with the sensing element placed horizontally at a depth of 10 cm, under one of the yield rows of the experiment. These instruments were observed periodically to determine if there were any measurable differences in the temperature of the experimental area and those observed at the Standard Climatological Station some 200 m, away. Temperature data taken at the two locations showed differences of less than 0.5 C. Therefore, the temperature data observed in the Climatological Station were used for this study.

Meteorological data measured in the Climatological Station are presented either on an incremental or a cumulative basis. Data on an incremental basis for each variable represent the values obtained for any one week. On the other hand, data on a cumulative basis represent the sum of a variable for the one week in question and the data cumulated for all the preceding weeks for the same treatment.

Meteorological data collected and used in this study were:

1. The daily maximum and minimum temperatures measured in a Cotton Region shelter were used to calculate degree day

heat units with a base of 2 C. The number of degree days per day is equal to the mean daily temperature minus the base temperature.

2. Total daily precipitation (mm.).
3. Total daily air movement measured by totalizing anemometer at 30 cm above ground (km.).
4. Total daily open pan evaporation (Standard U. S. Weather Bureau Class A pan) (mm.).
5. Total daily solar radiation recorded with bi-metallic pyrheliometer (langleys).
6. Day length, as time elapsed between sunrise and sunset (minutes).
7. Declination of the sun at solar noon for north latitude 35 degrees 53 minutes 30 seconds (seconds).
8. Soil moisture at depths of 15, 30, 45, and 60 cm., measured at the time a plot was harvested.

Soil samples were taken from the experimental plots in replications 1 and 2 each time a split-split-plot treatment was harvested. The samples were removed with a 5 cm. diameter bucket auger. The samples were taken to the laboratory in sealed containers not more than two hours after collection. They were weighed, dried at 105 C. for not less than 24 hours and re-weighed. The per cent water by weight was calculated and converted to per cent water by volume. The soil moisture tension at a given depth was calculated, using quadratic equations fitted to the moisture release curves of the experimental soil at each of the four depths from which samples were taken. These equations were obtained by using pressure plate and pressure membrane apparatus to measure the per cent water by volume at specified negative tensions. The quadratic equations were formulated from these data.

V. YIELD DATA COLLECTION AND USE

Uniform cuts of the yield rows were made with a hand sickle using an aluminum bar with 15 cm. legs as a guide to keep the stubble height uniformly at 15 cm. The guard rows were cut with a self-propelled Gravely mower equipped with a 75 cm. sickle bar and slides to maintain the cutting bar 15 cm. above ground level. The forage cut was removed immediately from the experimental area.

Plot yields of dry matter were obtained by harvesting the forage from the center 2.45 m. of the center row of each plot and placing the material in cotton bags. The material was dried at 70 C. for not less than 36 hours. In some cases more time was needed in order to dry very thick stems. After drying, the material was weighed to the nearest gram and weights recorded. When plots were harvested for yield, the plants were cut with a hand sickle at ground level. Data collection on a treatment stopped 2 or 3 weeks after head emergence. The dry matter yield data were used to plot the points of the cumulative dry matter yield curves for each treatment. Incremental dry matter yields were also calculated by determining the differences in the dry matter produced for each successive week of each treatment.

VI. APICAL MERISTEM AND STEM-LEAF RATIO DATA COLLECTION

Plants from an additional 15 cm. of row were removed for determinations of height of apical meristem and stem-leaf ratios. The whole plants, including some roots, were removed and the soil washed from the roots. This procedure was carried out in order to locate exactly the base of the stem. The height of apical meristem was determined by slicing the stems longitudinally with a razor blade, locating the meristematic tissue, and measuring the distance from the base of the stem to the apical meristems or, later on, to the mid-point of the developing inflorescence.

Stem-leaf ratios, on a dry weight basis, of material above the 15 cm. stubble height, were determined by separating the leaf blades from the sheaths. The "stem" portion included culm, leaf sheaths, and inflorescence.

VII. COMPUTATIONAL FACILITIES

Using programs previously developed at the University of Tennessee Computing Center, the data were processed with IBM 1460 and 7040 digital computers. The 1460 computer was used to convert plot weights of dry matter to kilograms of dry matter per hectare. The 1460 was used also for plotting the data presented as graphs on the latter pages of this text. The 7040 computer was used to compute stem-leaf ratios, soil moisture tension, and treatment mean yields, to perform various transgenerations of the data, and to calculate partial correlation coefficients.

CHAPTER IV

RESULTS AND DISCUSSION

Each treatment and each environmental variable used in this study has been assigned a mnemonic name for ease of discussion. The mnemonic names for each of the nine treatments are presented in Table I, accompanied by a detailed description. Mnemonic names for the 11 environmental variables are presented and described in Table II.

Cumulative dry matter production for the nine treatments are presented in Figures 1 and 2. The curves of Figures 1 and 2 represent the cumulative dry matter production curves measured in each treatment of planting date one and two, respectively. The curves are made of discrete points connected by a line rather than a curve fitted to points.

In the case of planting date one the cumulative dry matter curves tend to be sigmoid in shape. The first three are regular and smooth, but PL1CUT3 and PL1CUT4 are somewhat irregular.

All curves other than PL1CUT0 do not intersect the abscissa. This is because the first point of each such curve reflects the sum of the stubble remaining since the previous uniform cut and the growth for the first week of the treatment. Each succeeding curve starts at a higher distance from the abscissa, due to increasing stubble accumulation over time. In all treatments of planting date one, head emergence occurred at least two weeks before data collection was discontinued.

TABLE I

MNEMONIC NAME AND CUTTING MANAGEMENT FOR EACH TREATMENT

Mnemonic Name	Cutting Management: Planting Date	Cutting Management: Number of Uniform Cuts[a]	Cutting Management: Date of Last Uniform Cut of Each Treatment
PL1CUT0	1 (May 10)	0	
PL1CUT1	1	1	June 29
PL1CUT2	1	2	July 20
PL1CUT3	1	3	Aug. 10
PL1CUT4	1	4	Aug. 31
PL2CUT0	2 (June 20)	0	
PL2CUT1	2	1	Aug. 1
PL2CUT2	2	2	Aug. 22
PL2CUT3	2	3	Sept. 26

[a]Removal of 75 cm. growth above a 15 cm. stubble.

TABLE II

MNEMONIC NAME FOR EACH ENVIRONMENTAL VARIABLE

Mnemonic Name	Variable
CUMPREC	Cumulative Precipitation (cm.)
CUMWIND	Cumulative Wind (km.)
CUMRAD	Cumulative Total Radiation (langleys)
CUMPAN	Cumulative Pan Evaporation (cm.)
CUMHEAT	Cumulative Degree Day Heat Units 150 cm. Above Sod (2.0C.)
CUMDAY	Cumulative Day Length (minutes)
MEANDEC	Mean Solar Declination (seconds)
CUMTEN 15	Cumulative Soil Moisture Tension at 15 cm. Depth (bars)
CUMTEN 30	Cumulative Soil Moisture Tension at 30 cm. Depth (bars)
CUMTEN 45	Cumulative Soil Moisture Tension at 45 cm. Depth (bars)
CUMTEN 60	Cumulative Soil Moisture Tension at 60 cm. Depth (bars)

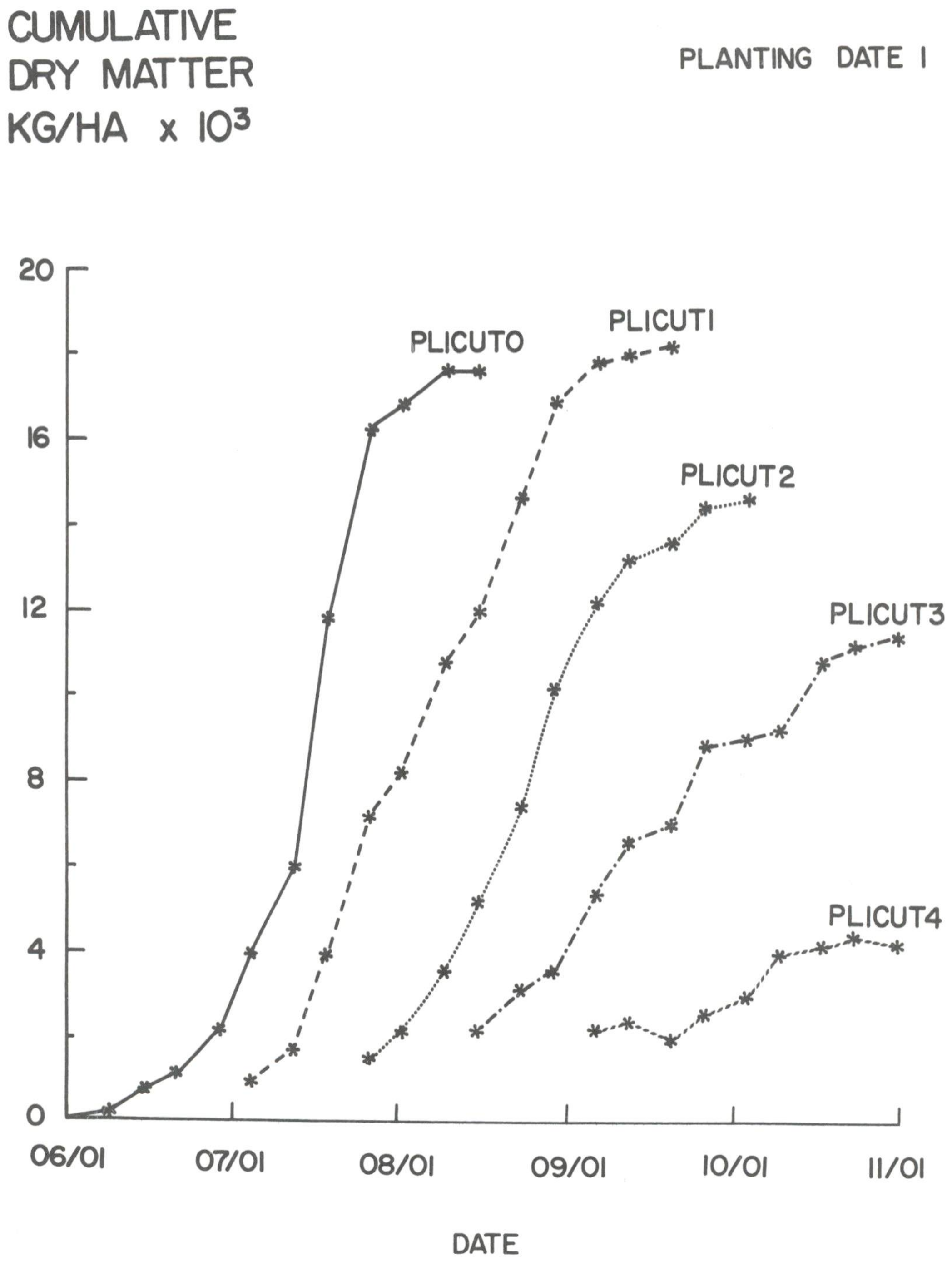

Figure 1. Cumulative dry matter production curves for the treatments of planting date one.

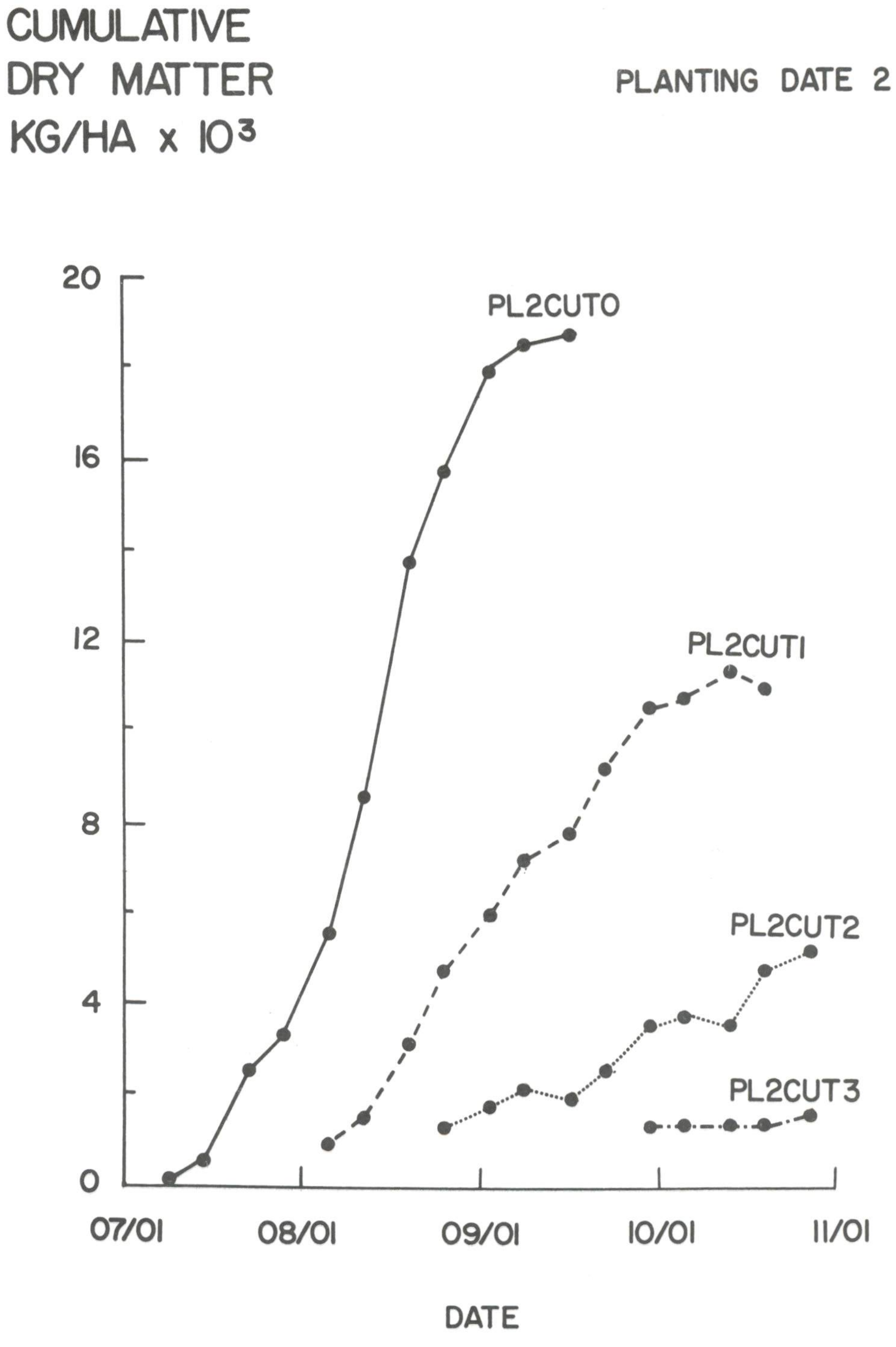

Figure 2. Cumulative dry matter production curves for the treatments of planting date two.

Therefore, the increase in dry matter during the last two weeks of a treatment was due primarily to seed development. In treatment PL1CUT4 the seed development during the last two weeks was very slow because of cool, cloudy weather. The slope of the curves was less steep toward the end of the season and as the number of uniform cuts increased. This may have been due to stand reduction. PL1CUT1, PL1CUT2, PL1CUT3, and PL1CUT4 produced 99, 74, 51, and 12 per cent as much dry matter as PL1CUT0, respectively.

Two of the four dry matter curves of planting date two were smooth, whereas curves PL2CUT1 and PL2CUT2 were irregular. PL1CUT3 was smooth since no growth was measured for that treatment. All the curves except PL2CUT3 tended to be sigmoid in shape. Some of the curves of Figure 2, like in Figure 1, started at different heights from the abscissa and had less steep slopes when the number of uniform cuts was increased. Treatments PL2CUT0 and PL2CUT1 headed about two weeks before data collection stopped. The increase in dry matter during the last two weeks was due primarily to seed development. Head emergence in treatment PL2CUT2 started about one week before data collection of the treatment stopped. PL2CUT1 produced approximately 19 per cent as much dry matter as PL2CUT0.

Figure 3 is a composite of Figures 1 and 2. Three of the treatments of planting date one grew at approximately the same time as three treatments of planting date two. Therefore, comparisons can be made between different cutting managements exposed to similar environment. Measurements of treatment PL2CUT0 were started five days after and

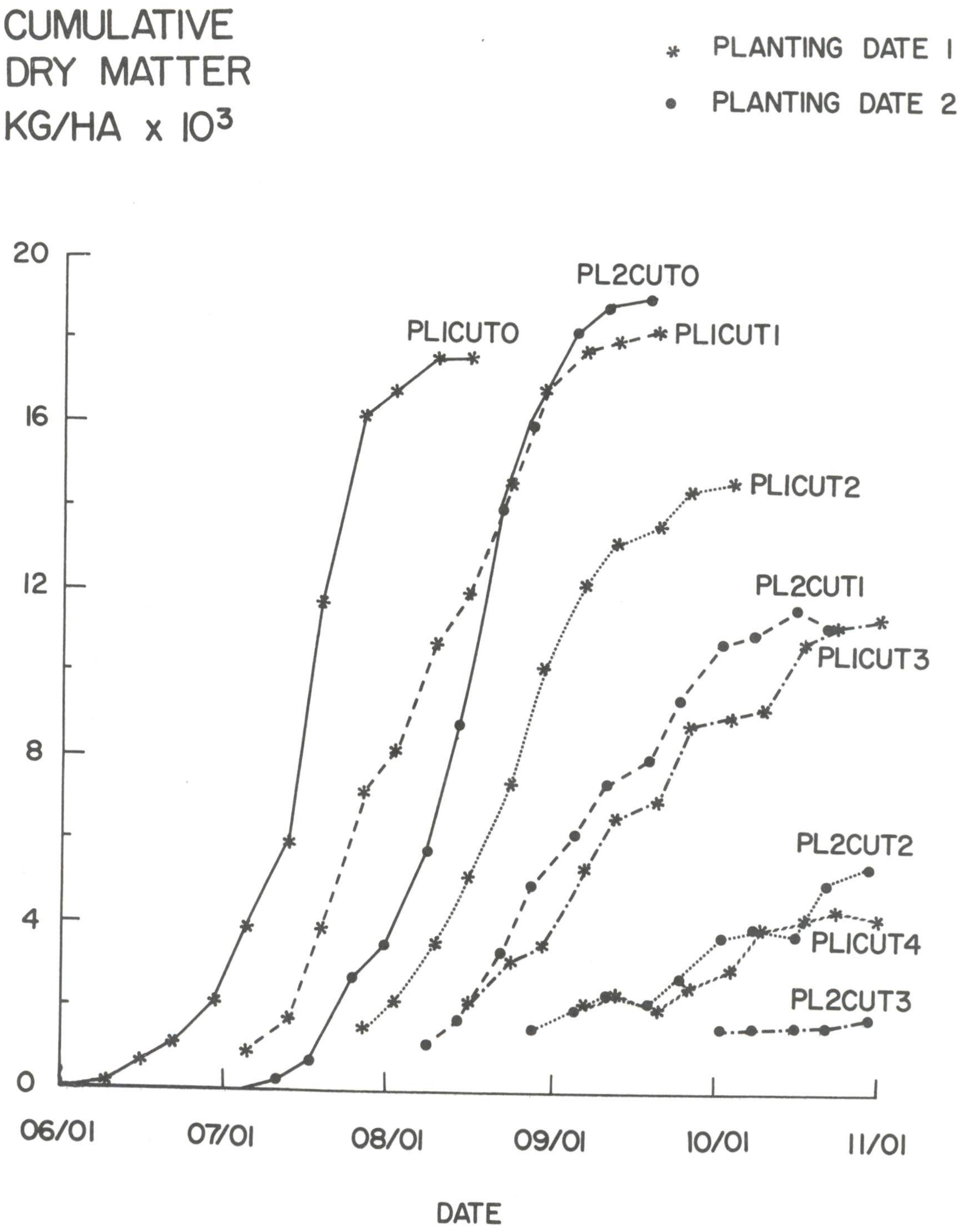

Figure 3. Cumulative dry matter production curves for all treatments.

stopped two days before measurements of PL1CUT1. Treatment PL2CUT0 produced 116 per cent as much dry matter as PL1CUT1, or about 18,000 kg/ha. in one less week. Treatment PL2CUT0 had a less dense stand than did PL1CUT0. At the end of the growing period plants of PL2CUT0 were about 15 to 25 cm. taller and had thicker stems than plants of PL1CUT1. Both PL2CUT1 and PL1CUT3 grew for 12 weeks. Measurements of PL2CUT3 were started nine days after and terminated nine days later than those of PL2CUT1. Treatment PL1CUT3 produced 86 per cent as much dry matter as PL1CUT3. Plants of PL2CUT3 were about 40 cm. taller than those of PL1CUT3. PL1CUT4 started nine days after and ended two days after PL2CUT2, producing 50 per cent as much dry matter, with the plants being approximately 40 cm. taller than those of PL2CUT2.

Within a planting date, increasing the number of uniform cuts decreased dry matter production. As the environment became less desirable, production was further reduced. Therefore, the two factors, cutting management and environment, appeared to be additive in their effect. This hypothesis is supported by the observation that, when curves of the two planting dates occurred simultaneously, treatments receiving fewer uniform cuts had higher rates of production.

Total dry matter production and mean daily dry matter production during selected periods for each treatment are presented in Table III. The total production and mean daily production were calculated for a period of time which extended from the second to the one-before-last week of data collection for each treatment. Both total production and mean daily production decreased as the number of uniform cuts increased.

TABLE III

TOTAL AND AVERAGE DAILY DRY MATTER PRODUCTION DURING DIFFERENT GROWING PERIODS FOR EACH TREATMENT

Treatment	Total Dry Matter Production	Average Production Per Day	Beginning Date	Ending Date	Days In Period
	KG./HA.	KG./HA.			
PL1CUT0	17242	273.6	06/08	08/10	63
PL1CUT1	19120	244.6	07/06	09/14	70
PL1CUT2	12691	201.5	07/27	09/28	63
PL1CUT3	8903	127.3	08/17	10/26	70
PL1CUT4	1924	46.0	09/07	10/26	49
PL2CUT0	18395	292.0	07/11	09/12	63
PL2CUT1	10313	147.2	08/08	10/17	70
PL2CUT2	3435	61.3	08/29	10/24	56
PL2CUT3	55	2.6	10/03	10/24	21

The greatest rate of production was in treatment PL2CUT0 with a mean daily production of 292 kg/ha. or 29.2 g/m.^{2} for a 63 day period. The maximum rate of production per day for a one-week period, 83.7 g/m.^{2}/day, occurred in treatment PL1CUT0 during the week beginning on July 6. This value surpassed the 44 g/m.^{2}/day reported by Begg (4).

The relationships between height of apical meristem and cumulative dry matter production are illustrated in Figures 4 and 5. The height of apical meristem curves closely paralleled those of dry matter production for several of the treatments. The greatest deviation occurred at and after head emergence. The greater variation observed in treatments PL2CUT1 and PL2CUT2 may have been due to a thinner stand and, correspondingly, less competition among plants. Generally, the height of apical meristems of treatments of planting date two was greater than in those of planting date one at head emergence.

The relationships among cumulative dry matter and some of the cumulative environmental variables are presented graphically in Appendix A. Generally, the cumulative dry matter yield curves were paralleled by the curves of each cumulative environmental factor except those for CUMPREC. The cumulative dry matter yield curves were less closely paralleled by curves for cumulative environmental factors during the last one-third of the growing season. In such cases the slopes of the curves of the environmental factors were steeper than those of the corresponding dry matter yield curves. This discrepancy during the last one-third of the season, therefore, may have been due to factors other than the environmental variables measured, taken one at a time. It

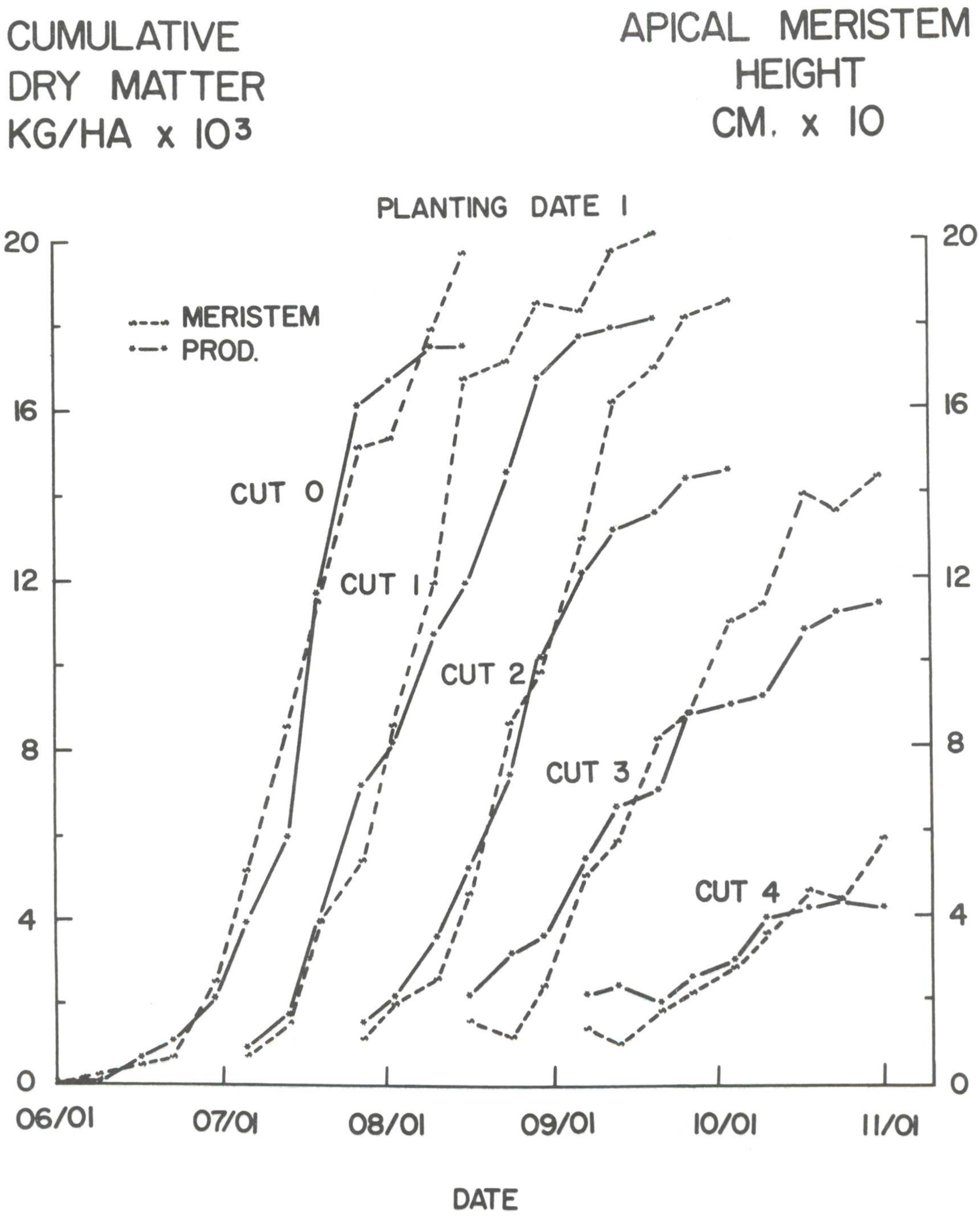

Figure 4. Cumulative dry matter production and height of apical meristem curves for treatments of planting date one.

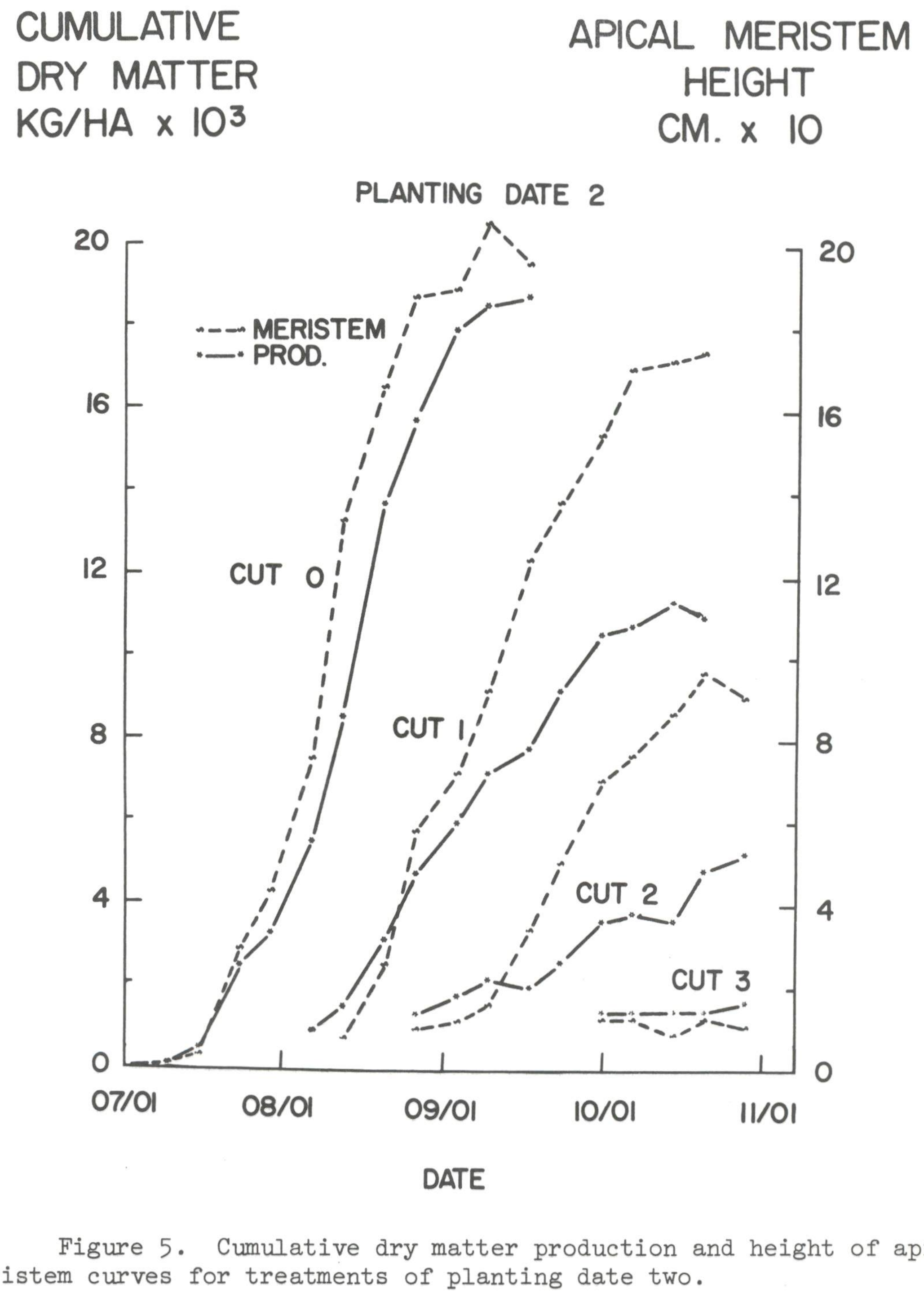

Figure 5. Cumulative dry matter production and height of apical meristem curves for treatments of planting date two.

may have been due to effects of age or repeated cutting of the plants, or to a combination of such effects with one or more environmental effects.

Tables of cumulative soil moisture tension at depths of 15, 30, 45, and 60 cm. for each treatment are presented in Appendix B. There was an above-normal, but not excessive, amount of well-distributed precipitation during the months of June through October with only one two-week period not receiving rain. During that five-month period, 68 cm. of precipitation were recorded, as compared to a long-term average of 43 cm. for the same period of time. Generally soil moisture tension was less than five bars throughout the growing season. Toward the end of the two-week period not receiving rain, tensions of 12 bars were calculated for some of the plots in which plants were rapidly growing.

No attempt was made to relate either the heights of apical meristem or the stem-leaf ratios to the environmental variables by statistical means. Tables of the treatment means and associated standard deviations for dry matter production, height of apical meristem, and stem-leaf ratios for each treatment are presented in Appendix C.

Cumulative dry matter yields of the nine treatments were correlated with each of the 11 environmental variables listed in Table II, page 25. The 11 partial correlation coefficients for each of the nine treatments are presented in Table IV. Seventy-eight of the 99 partial correlation coefficients were greater than 0.9, seven were between 0.8 and 0.9 and the remaining 14 were less than 0.8 but greater than 0.64.

TABLE IV

PARTIAL CORRELATION COEFFICIENTS OF CUMULATIVE DRY MATTER PRODUCTION WITH EACH ENVIRONMENTAL VARIABLE ON A CUMULATIVE BASIS FOR EACH TREATMENT

Variable	Treatment								
	PL1CUT0	PL1CUT1	PL1CUT2	PL1CUT3	PL1CUT4	PL2CUT0	PL2CUT1	PL2CUT2	PL1CUT3
CUMPREC	.903	.964	.957	.967	.914	.982	.846	.963	.715
CUMWIND	.957	.997	.968	.972	.951	.979	.970	.973	.794
CUMRAD	.957	.992	.986	.991	.950	.980	.990	.959	.764
CUMPAN	.959	.995	.987	.991	.952	.980	.990	.956	.742
CUMHEAT	.970	.991	.986	.994	.925	.981	.995	.942	.768
CUMDAY	.960	.988	.979	.990	.937	.978	.986	.962	.790
MEANDEC	-.884	-.955	-.964	-.986	-.941	-.973	-.960	-.966	-.786
CUMTEN15	.963	.937	.939	.992	.938	.876	.941	.854	.797
CUMTEN30	.957	.956	.956	.942	.960	.845	.980	.839	.797
CUMTEN45	.918	.984	.987	.960	.772	.986	.968	.677	.797
CUMTEN60	.915	.973	.923	.970	.648	.988	.972	.881	.797

In view of the extremely high partial correlation coefficients obtained using cumulative dry matter and cumulative environmental variables, correlations were computed also using incremental dry matter production and incremental environmental data. The 11 partial correlation coefficients using the environmental data for each treatment are presented in Table V. The partial correlation coefficients were generally low. Only 15 were greater than 0.7 and the other 84 were less than this value. Therefore, it is doubtful that the partial correlation coefficients calculated using cumulative dry matter and cumulative environmental variables are meaningful. One possible reason for this disagreement was the small number of residual degrees of freedom available (from three to ten). A partial correlation coefficient of 0.576 at the 0.05 level of probability with ten degrees of freedom would be required in order for the true correlation to be greater than zero. The corresponding value for three degrees of freedom would be 0.878.

In view of the questionable nature of the partial correlation coefficients between dry matter production and the environmental variables, no attempt was made to perform a regression analysis or to formulate a prediction equation for dry matter production.

TABLE V

PARTIAL CORRELATION COEFFICIENTS OF INCREMENTAL DRY MATTER PRODUCTION WITH EACH ENVIRONMENTAL VARIABLE ON AN INCREMENTAL BASIS FOR EACH TREATMENT

Variable	Treatment								
	PL1CUT0	PL1CUT1	PL1CUT2	PL1CUT3	PL1CUT4	PL2CUT0	PL2CUT1	PL2CUT2	PL2CUT3
CUMPREC	.450	.183	-.143	-.329	-.093	.034	-.096	.046	-.611
CUMWIND	.175	-.662	-.214	.223	.510	-.653	-.001	.600	-.371
CUMRAD	-.658	-.466	-.799	-.807	-.430	-.649	-.691	-.598	-.359
CUMPAN	-.197	-.634	-.920	-.834	-.452	-.701	-.842	-.686	-.673
CUMHEAT	.114	.287	-.054	-.134	-.294	-.041	-.037	.326	.768
CUMDAY	.850	.150	-.703	.113	.632	-.179	-.066	.523	-.796
MEANDEC	-.884	-.955	-.197	.447	.494	-.973	.345	.495	-.785
CUMTEN15	.471	-.113	.004	-.188	.323	.347	-.014	-.268	.001
CUMTEN30	.440	.203	-.258	-.088	-.467	-.059	-.078	-.269	.001
CUMTEN45	.702	.386	-.166	-.265	-.556	.459	-.466	-.359	.001
CUMTEN60	.649	.557	-.136	-.458	-.693	.451	-.589	-.442	-.334

CHAPTER V

SUMMARY AND CONCLUSIONS

Approximately 140,000 acres of summer annual forages were grown by Tennessee farmers in 1966. Sorghum-sudangrass hybrids are accepted and widely used, but little is known about their growth and regrowth after harvesting. In order to maximize yields and profits, the producer must know when to harvest a crop for the most suitable combination of quality and yield.

An experiment was conducted to determine the effects of environment and cutting management on the growth rates and regrowth rates after harvest of a sorghum-sudangrass hybrid (Sudax SX-11). Dry matter production curves were constructed for this purpose by harvesting plots of a treatment at weekly intervals. Such meteorological data as daily maximum and minimum temperatures, daily precipitation, daily total radiation, and others, were collected and used either on an incremental or cumulative basis. Such plant characteristics as stem-leaf ratio and height of apical meristem were related to dry matter production. Dry matter production curves were constructed for this purpose.

The following conclusions were drawn:

1. Intraseasonal distribution of dry matter production was affected by both cutting management and environment.
2. Increasing the number of harvests reduced dry matter production potential. This was believed to be due to stand reduction and general loss of vigor by the plants.

3. Dry matter production potential also was limited by the environment. The environmental factors measured which were probably most limiting to production were total radiation, temperature, soil moisture, and day length.
4. Treatments planted early and not cut or cut once, and treatments planted six weeks later and not cut, produced from 17,000 to 18,000 kg/ha. Treatments planted early and cut four times, and treatments planted six weeks later and cut two or three times, produced 3,000 to 4,000 kg/ha. Treatments planted early and cut two or three times, and treatments planted six weeks later and cut once, produced yields intermediate to these two extremes. The maximum rate of dry matter production for a one-week period was 83.7 $g/m^2/day$.
5. The seasonal distribution of dry matter production in June, July, and August could be altered by manipulation of combinations of planting date and cutting management.
6. Dry matter yields accumulated over time were highly correlated with several environmental factors accumulated in a similar manner. However, the correlation coefficients were not necessarily indicative of the degree of association among variables due to the small number of degrees of freedom available. Future work of this type should be designed in such a way that more degrees of freedom must be available than were available in this study, if the formulation of yield prediction equations is the objective.

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APPENDIXES

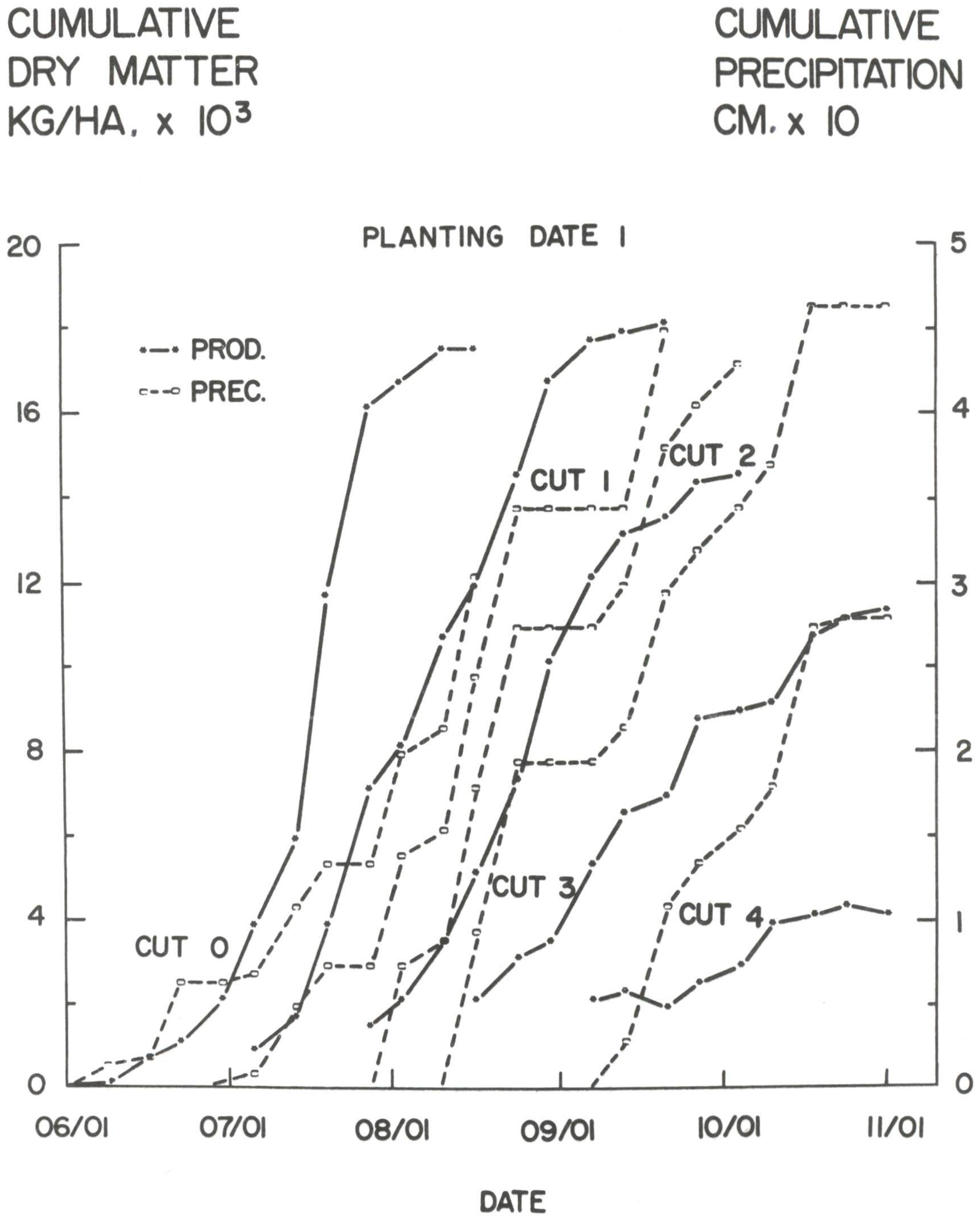

Figure 6. Cumulative dry matter production and precipitation curves for treatments of planting date one.

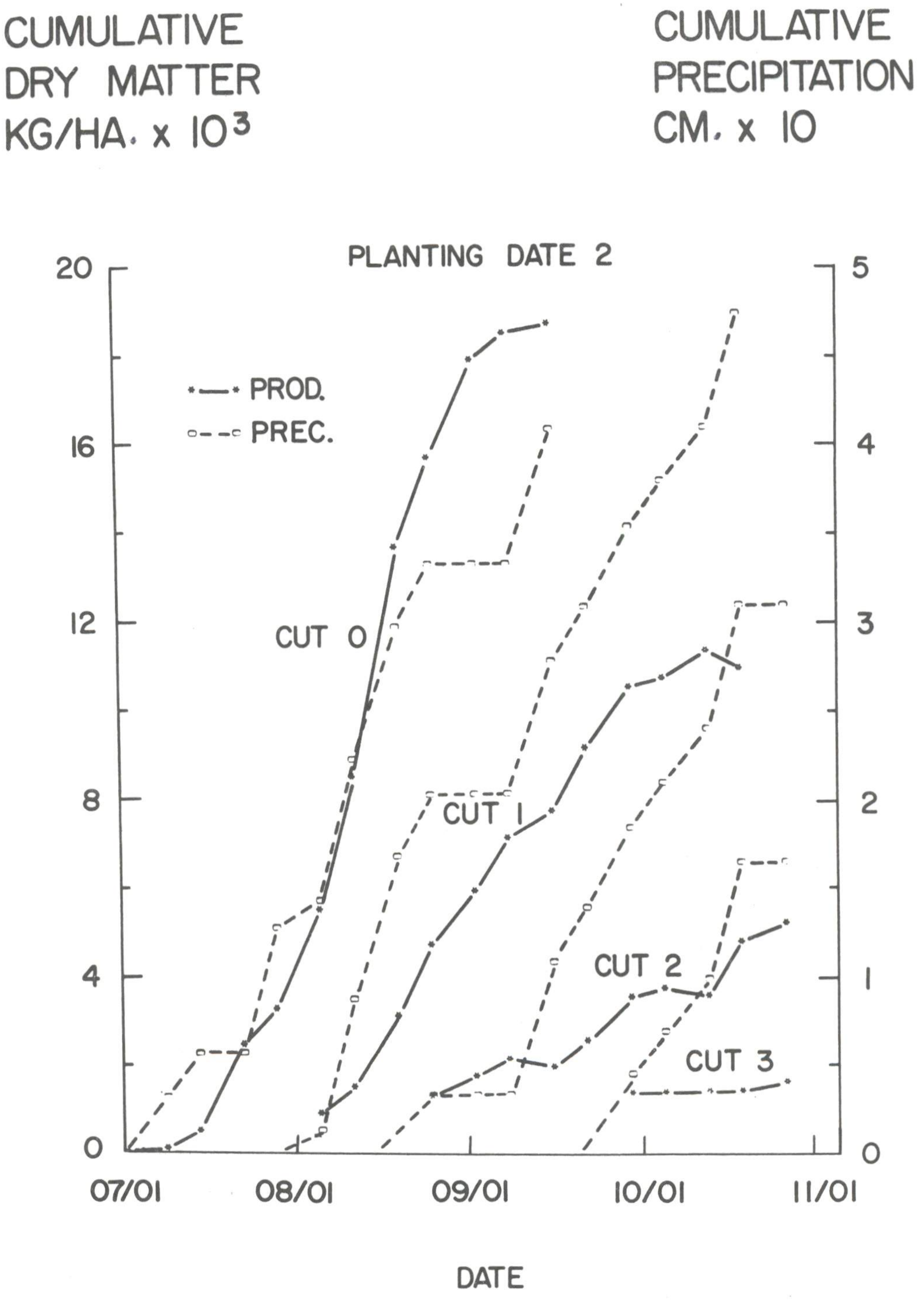

Figure 7. Cumulative dry matter production and precipitation curves for treatments of planting date two.

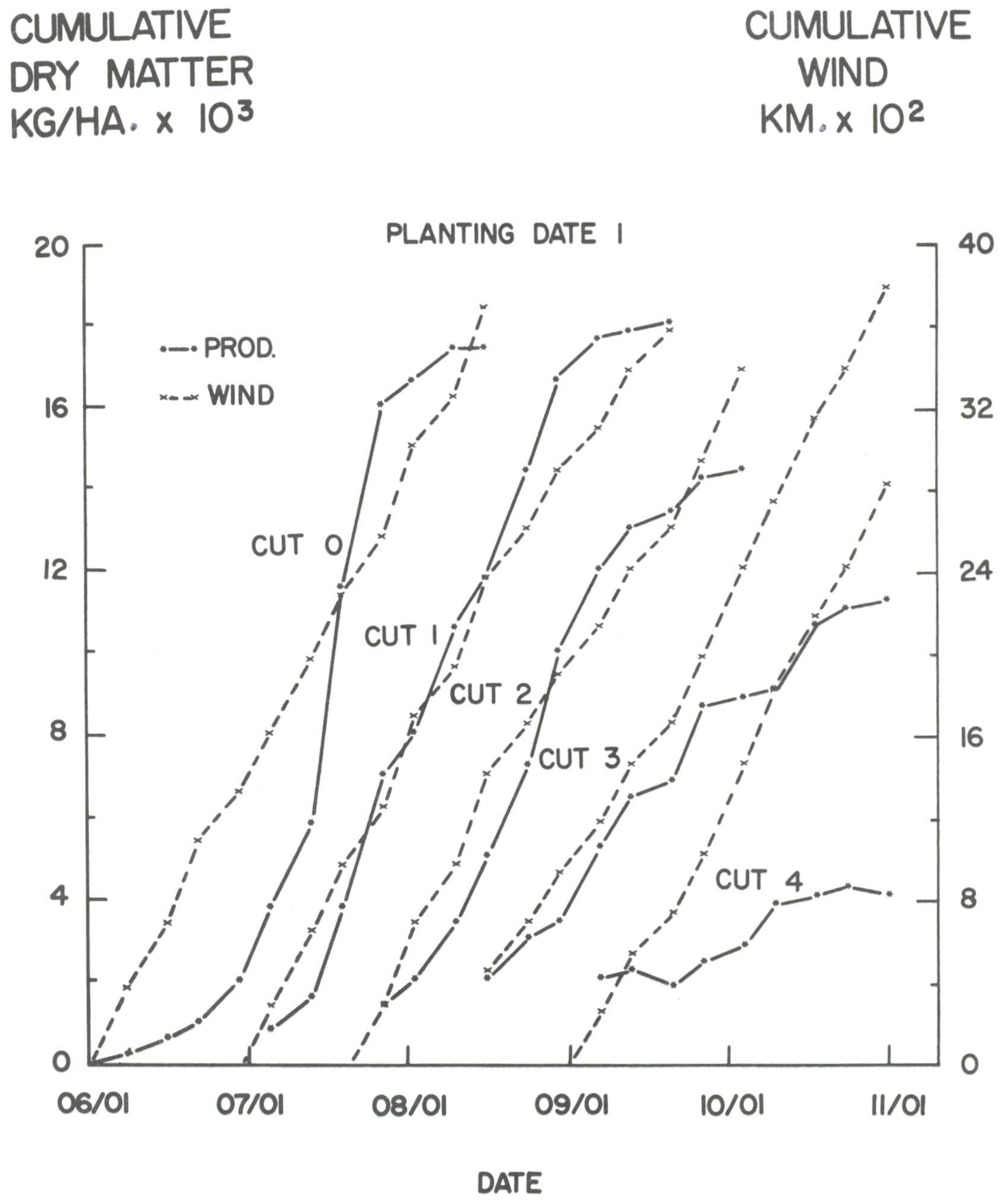

Figure 8. Cumulative dry matter production and wind curves for treatments of planting date one.

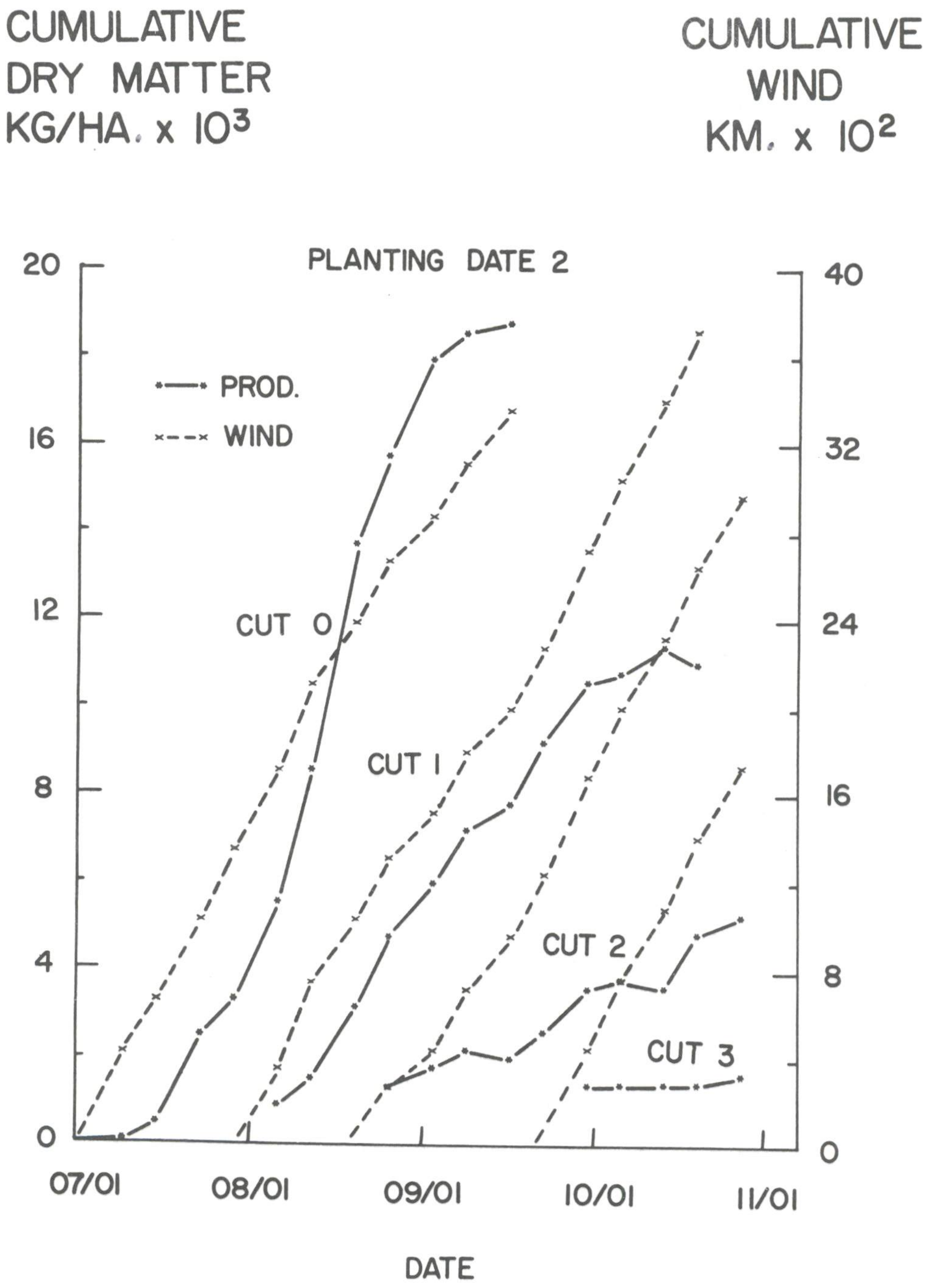

Figure 9. Cumulative dry matter production and wind curves for treatments of planting date two.

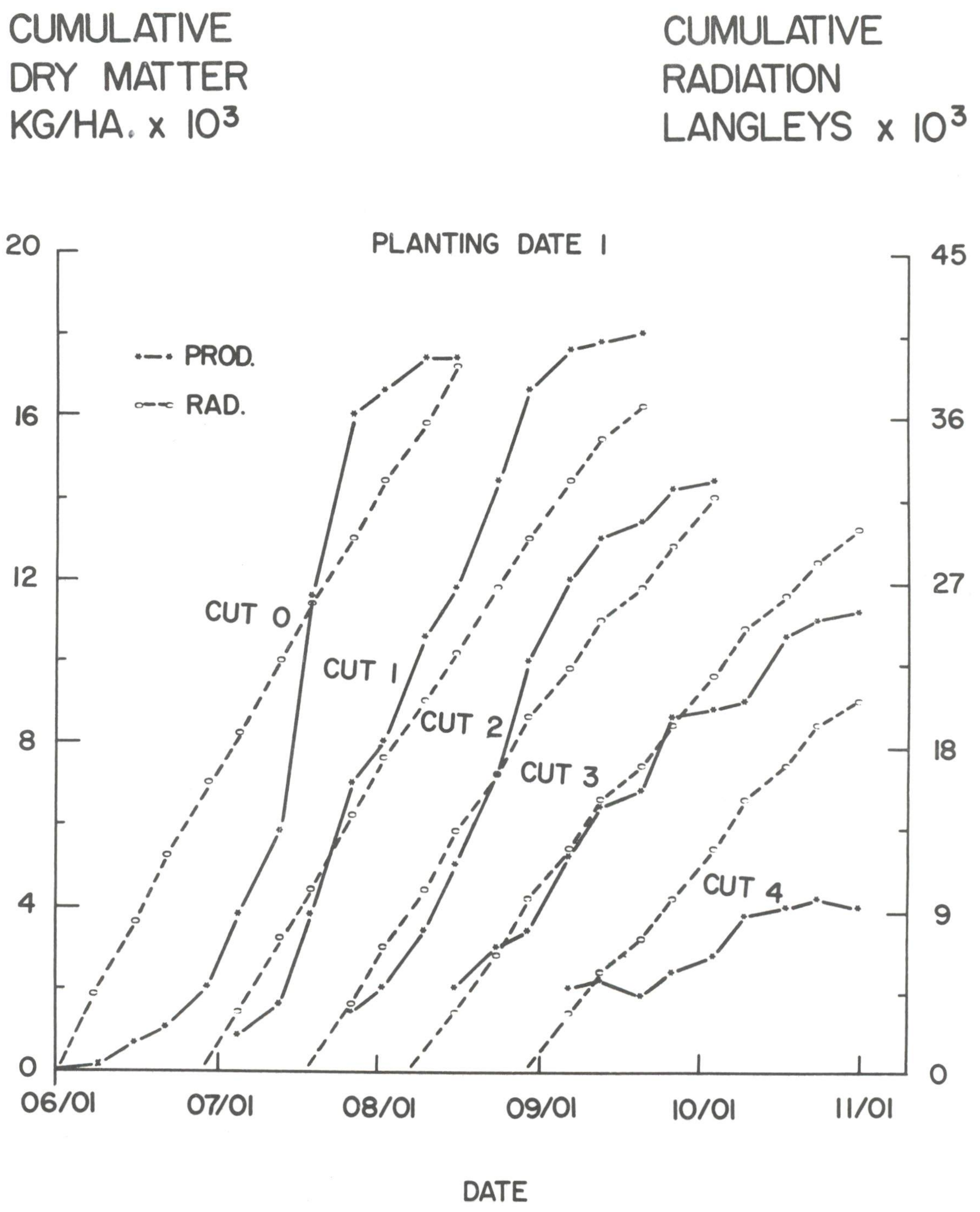

Figure 10. Cumulative dry matter production and radiation curves for treatments of planting date one.

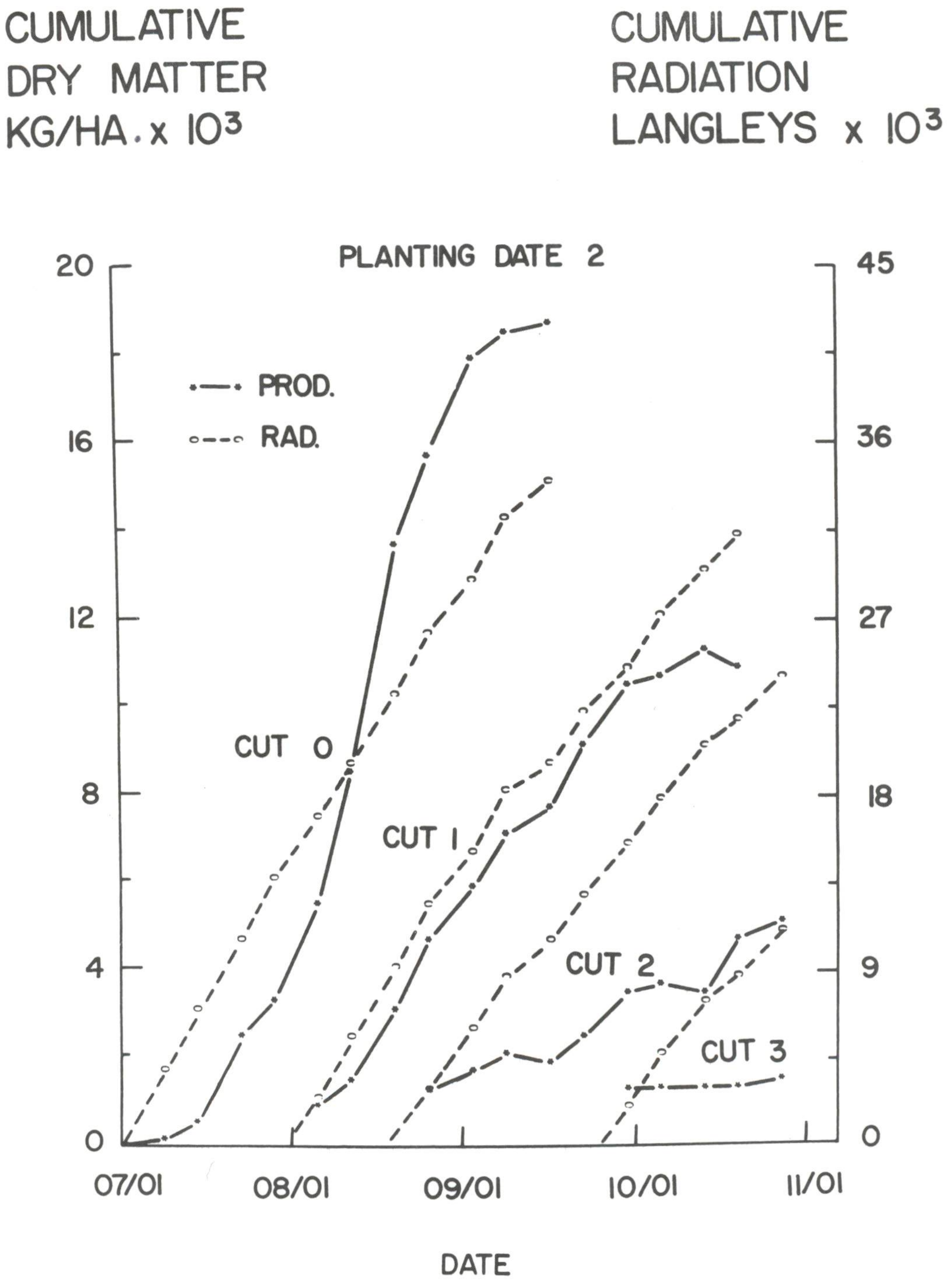

Figure 11. Cumulative dry matter production and radiation curves for treatments of planting date two.

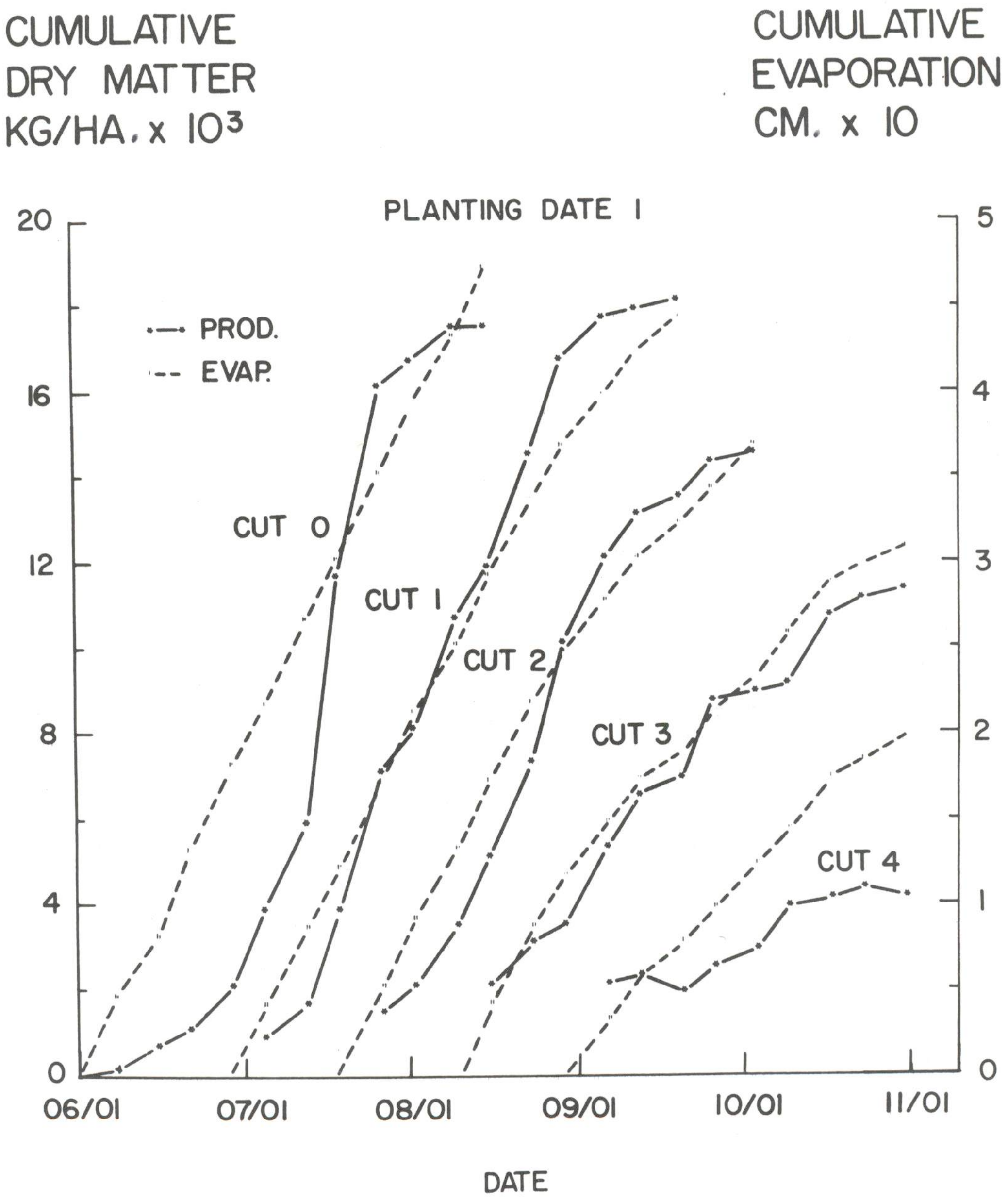

Figure 12. Cumulative dry matter production and evaporation curves for treatments of planting date one.

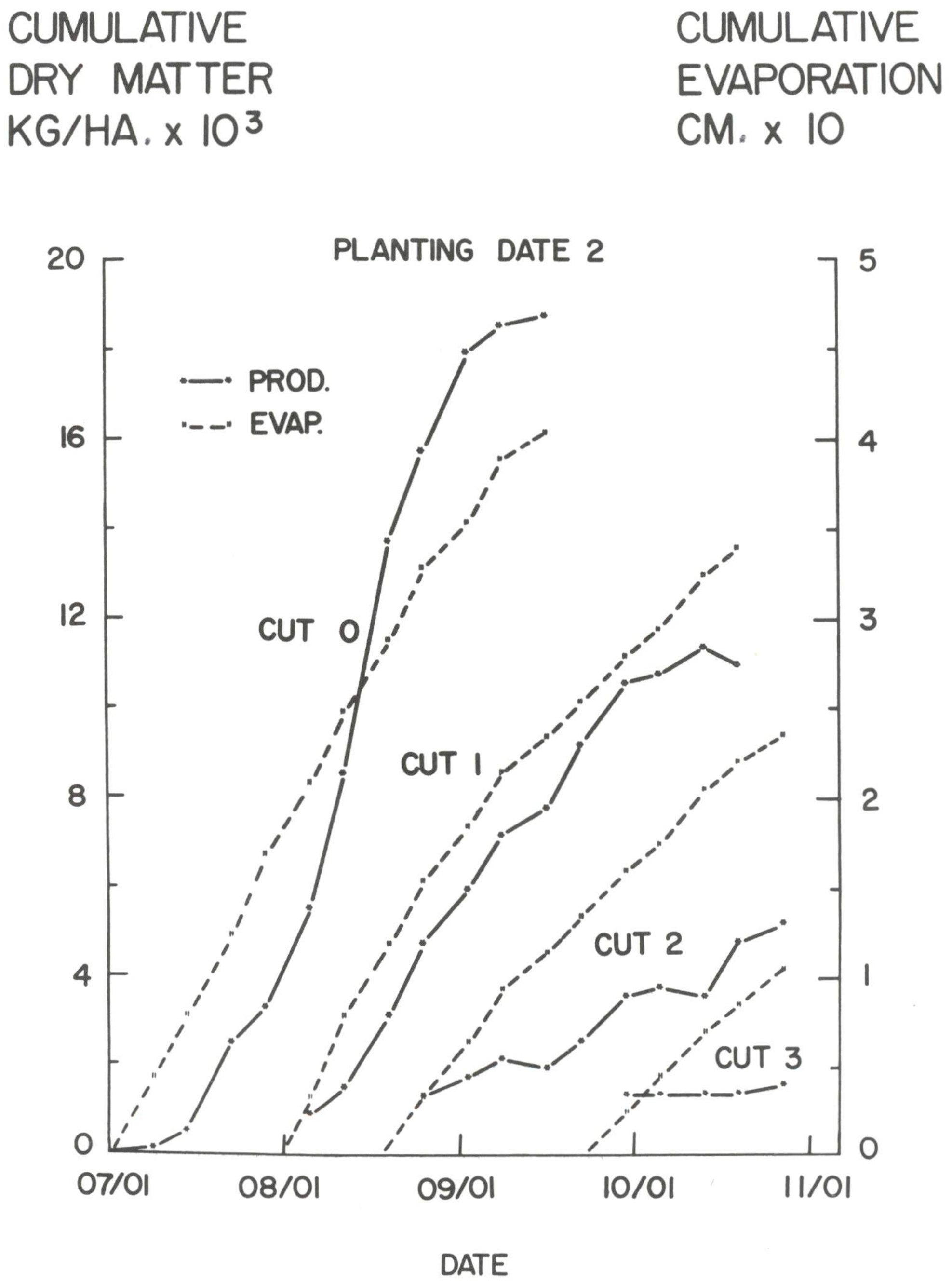

Figure 13. Cumulative dry matter production and evaporation curves for treatments of planting date two.

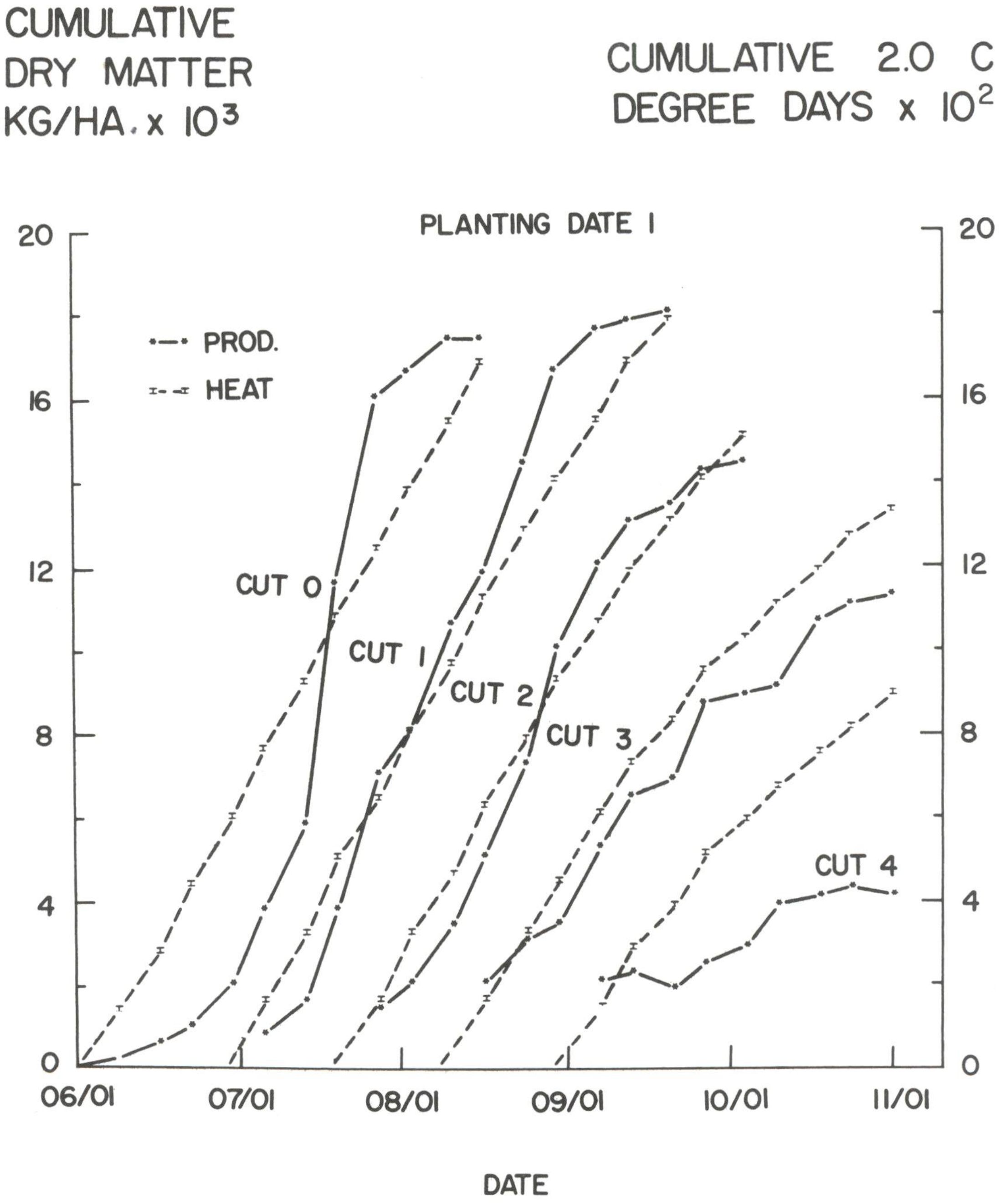

Figure 14. Cumulative dry matter production and degree day curves for treatments of planting date one.

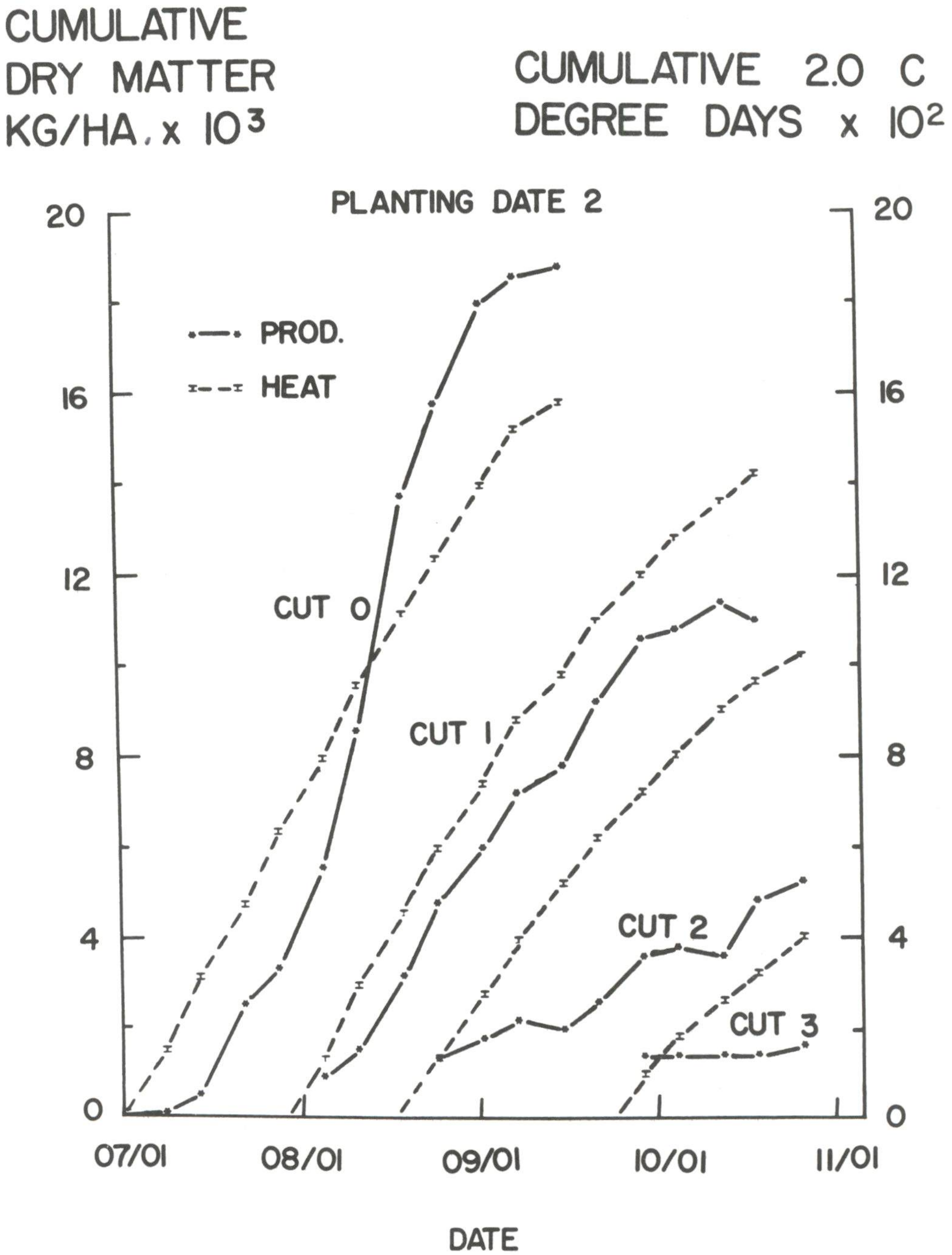

Figure 15. Cumulative dry matter production and degree day curves for treatments of planting date two.

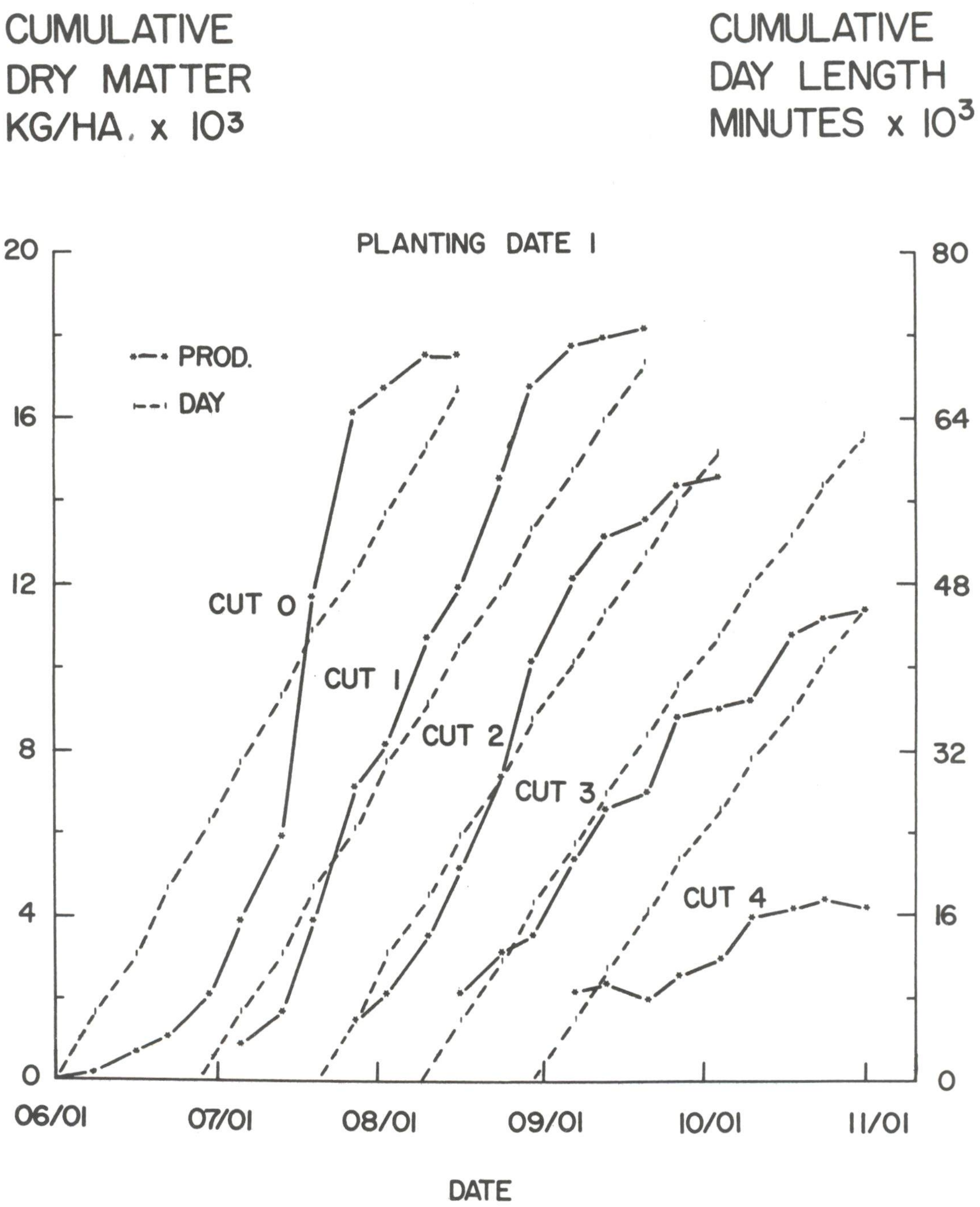

Figure 16. Cumulative dry matter production and day length curves for treatments of planting date one.

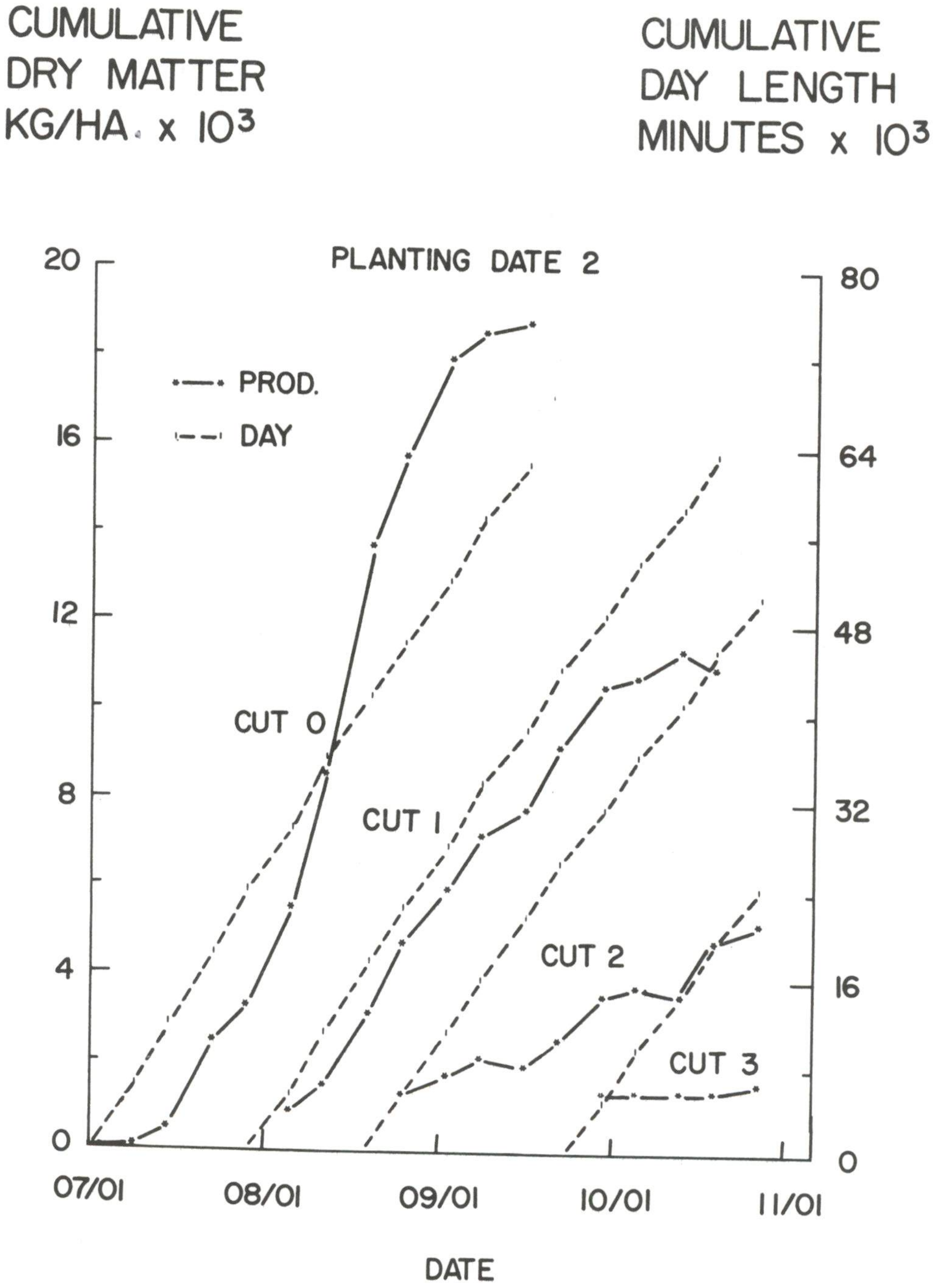

Figure 17. Cumulative dry matter production and day length curves for treatments of planting date two.

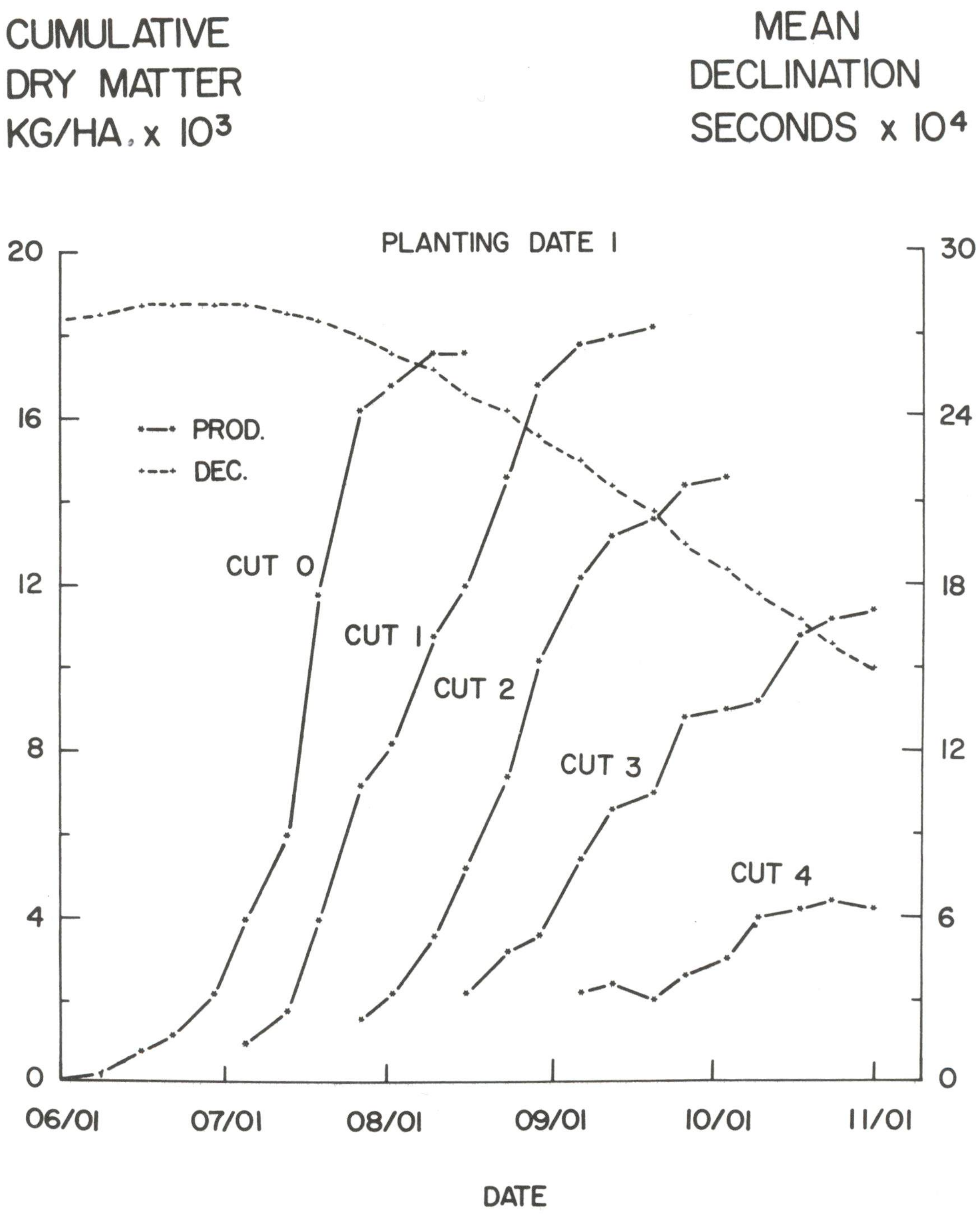

Figure 18. Cumulative dry matter production and mean solar declination curves for treatments of planting date one.

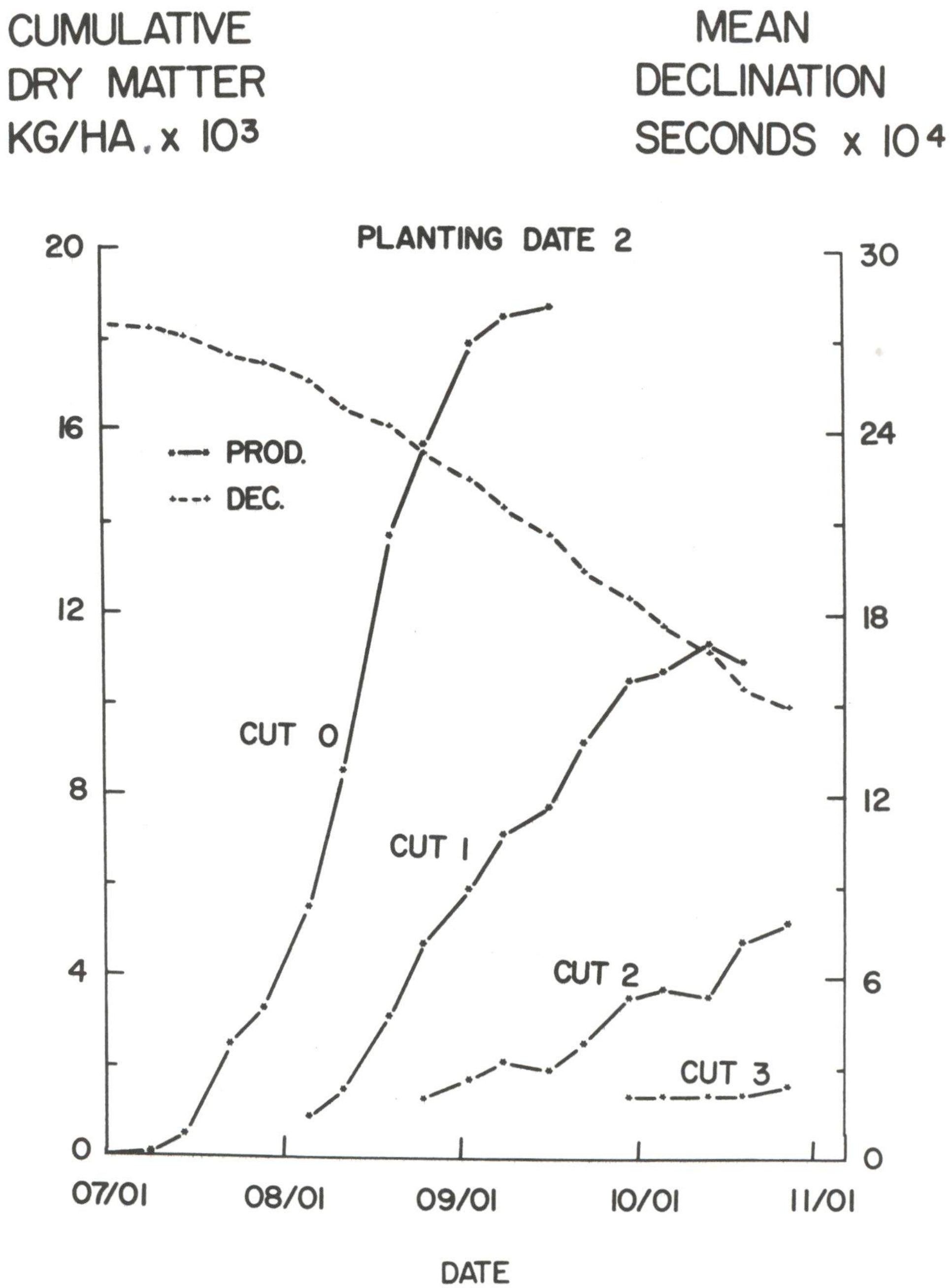

Figure 19. Cumulative dry matter production and mean solar declination curves for treatments of planting date two.

APPENDIX B

TABLE VI

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL1CUTO

WEEK BEGINNING ON	DEPTH IN CM. 15	30	45	60
06/08	0.33	0.33	0.33	0.33
06/15	0.66	0.66	0.66	0.66
06/22	0.99	0.99	0.99	0.99
06/29	1.32	1.32	1.32	1.32
07/06	1.65	1.65	1.65	1.65
07/13	1.98	1.98	1.98	1.98
07/20	11.57	5.84	5.84	3.29
07/27	27.91	18.42	19.66	13.45
08/03	28.24	18.75	28.14	18.50
08/10	32.28	20.94	35.04	22.90
08/17	32.61	21.27	35.37	23.23

TABLE VII

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM, FOR TREATMENT PL1CUT1

WEEK BEGINNING ON	DEPTH IN CM.			
	15	30	45	60
07/06	0.33	0.33	0.33	0.33
07/13	0.66	0.66	0.66	0.66
07/20	0.99	0.99	2.68	1.76
07/27	11.48	7.22	12.73	8.32
08/03	11.81	7.55	21.48	10.89
08/10	13.56	11.69	30.40	17.37
08/17	13.89	12.02	40.06	21.81
08/24	14.22	12.35	49.01	29.51
08/31	14.55	12.68	53.04	30.24
09/07	16.96	15.76	59.60	34.10
09/14	17.29	21.03	70.74	40.01
09/21	17.62	21.36	71.07	46.29

TABLE VIII

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL1CUT2

WEEK BEGINNING ON	DEPTH IN CM. 15	30	45	60
07/27	2.25	3.26	0.94	5.15
08/03	2.58	3.79	5.15	8.25
08/10	2.91	4.12	9.38	10.31
08/17	3.24	4.45	14.96	13.73
08/24	3.57	4.78	15.29	14.18
08/31	3.90	5.11	20.05	15.50
09/07	8.58	7.61	25.59	16.96
09/14	8.91	8.43	29.32	18.94
09/21	9.24	8.76	29.65	25.22
09/28	9.57	9.09	31.43	27.18
10/05	9.90	9.42	33.33	30.00

TABLE IX

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL1CUT3

WEEK BEGINNING ON	DEPTH IN CM. 15	30	45	60
08/17	0.33	0.33	0.53	1.45
08/24	0.66	0.66	1.89	6.16
08/31	0.99	0.99	4.24	7.57
09/07	2.30	1.37	8.91	9.65
09/14	2.63	6.79	17.42	12.37
09/21	2.96	7.12	17.75	18.65
09/28	3.29	7.45	21.08	21.34
10/05	3.62	7.78	21.95	22.85
10/12	3.95	8.11	22.28	23.18
10/19	4.28	8.44	22.61	23.51
10/26	4.61	8.77	22.94	23.84
11/02	4.94	9.10	23.27	24.17

TABLE X

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL1CUT4

WEEK BEGINNING ON	DEPTH IN CM. 15	30	45	60
09/07	0.33	0.78	4.45	1.48
09/14	0.66	2.34	7.42	6.59
09/21	0.99	2.67	7.75	12.87
09/28	1.32	3.00	8.14	13.20
10/05	1.65	3.33	8.47	13.53
10/12	1.98	3.66	8.80	13.86
10/19	2.31	3.99	9.13	14.19
10/26	2.64	4.32	9.46	14.52
11/02	2.97	4.65	9.79	14.85

TABLE XI

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL2CUTO

WEEK BEGINNING ON	DEPTH IN CM,			
	15	30	45	60
07/11	0.33	0.33	0.33	0.33
07/18	0.66	0.66	0.66	0.66
07/25	6.66	6.58	0.99	0.99
08/01	6.99	6.91	5.33	2.26
08/08	7.32	7.24	6.89	4.70
08/15	7.65	7.57	12.99	7.14
08/22	7.98	7.90	17.55	14.31
08/29	13.17	8.23	22.22	18.03
09/05	14.30	8.61	25.34	19.03
09/12	25.19	12.31	31.22	23.36
09/19	25.52	12.64	31.55	23.69

TABLE XII

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL2CUT1

WEEK BEGINNING ON	DEPTH IN CM.			
	15	30	45	60
08/08	0.33	0.33	2.40	0.41
08/15	0.66	0.66	5.14	3.50
08/22	0.99	0.99	7.18	7.52
08/29	1.32	1.32	8.82	8.96
09/05	4.50	3.19	11.92	10.87
09/12	12.52	4.24	18.51	13.24
09/19	12.85	4.57	18.84	13.57
09/26	13.18	4.90	19.19	14.69
10/03	13.51	5.23	19.85	15.55
10/10	13.84	5.56	20.18	15.88
10/17	14.17	5.89	20.51	16.21
10/24	14.50	6.22	20.84	16.54

TABLE XIII

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL2CUT2

WEEK BEGINNING ON	DEPTH IN CM. 15	30	45	60
08/29	0.33	0.33	1.54	0.50
09/05	0.66	0.66	3.48	2.56
09/12	3.16	3.51	16.60	4.41
09/19	3.49	3.84	16.93	4.74
09/26	3.82	4.17	17.26	5.07
10/03	4.15	4.50	17.59	6.17
10/10	4.48	4.83	17.92	6.50
10/17	4.81	5.16	18.25	6.83
10/24	5.14	5.49	18.58	7.16
10/31	5.47	5.82	18.91	7.49

TABLE XIV

CUMULATIVE WEEKLY SOIL MOISTURE TENSION, IN BARS, AT DEPTHS OF 15, 30, 45, AND 60 CM. FOR TREATMENT PL2CUT3

WEEK BEGINNING ON	DEPTH IN CM.			
	15	30	45	60
10/03	0.33	0.33	0.33	8.32
10/10	0.66	0.66	0.66	8.65
10/17	0.99	0.99	0.99	8.98
10/24	1.32	1.32	1.32	9.31
10/31	1.65	1.65	1.65	9.64

APPENDIX C

TABLE XV

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG./HA.), HEIGHT OF APICAL MERISTEM (CM.), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL1CUTO

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG./HA.		CM.			
06/08	82	16.9	1.6	0.0	1.00	0.00
06/15	550	100.9	3.2	1.1	0.44	0.09
06/22	1007	197.6	5.2	1.4	0.22	0.03
06/29	2063	154.8	24.5	6.7	0.58	0.10
07/06	3876	894.5	49.9	22.6	1.00	0.33
07/13	5745	369.3	83.5	33.7	1.68	0.45
07/20	11606	1515.1	113.6	53.9	2.33	0.35
07/27	15933	2271.7	149.7	52.9	3.11	0.75
08/03	16602	1132.1	152.8	63.9	3.24	0.64
08/10	17324	2463.1	178.5	53.1	5.34	0.42
08/17	17321	1732.6	195.4	39.3	5.22	1.08

TABLE XVI

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL1CUT1

WEEK BEGINNING ON	DRY MATTER PRODUCTION MEAN	DRY MATTER PRODUCTION STANDARD DEVIATION	HEIGHT OF APICAL MERISTEM MEAN	HEIGHT OF APICAL MERISTEM STANDARD DEVIATION	STEM-LEAF RATIO MEAN	STEM-LEAF RATIO STANDARD DEVIATION
	KG/HA.		CM.			
07/06	753	35.8	6.5	5.7	0.22	0.04
07/13	1592	116.3	13.2	10.7	0.60	0.05
07/20	3722	1020.8	38.2	20.9	1.16	0.78
07/27	6958	343.9	52.9	37.4	1.66	0.16
08/03	8083	1162.7	84.2	38.2	1.84	0.20
08/10	10552	644.1	117.0	50.8	3.14	0.94
08/17	11798	999.4	166.7	38.6	3.92	0.65
08/24	14423	1676.2	170.5	41.2	5.50	0.29
08/31	16607	1103.0	184.9	32.6	4.31	0.31
09/07	17595	3336.0	182.8	29.9	4.91	0.25
09/14	17873	2272.7	195.7	26.2	5.56	0.45
09/21	18036	1771.8	199.3	21.5	4.83	0.25

TABLE XVII

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL1CUT2

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG/HA.		CM.			
07/27	1448	202.7	10.5	5.3	0.63	0.12
08/03	1992	159.4	18.2	8.6	0.69	0.11
08/10	3421	396.9	23.9	16.6	0.96	0.07
08/17	5051	257.2	44.1	26.7	1.48	0.48
08/24	7287	693.5	84.3	33.5	1.82	0.31
08/31	10002	1979.0	96.7	66.4	2.63	0.54
09/07	12055	689.4	127.9	68.7	3.41	0.50
09/14	13013	1555.9	159.0	64.5	3.91	0.21
09/21	13494	522.0	167.6	70.5	4.83	0.51
09/28	14140	245.1	180.8	45.9	4.72	0.20
10/05	14314	1005.2	183.2	47.9	4.92	0.28

TABLE XVIII

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL1CUT3

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG/HA.		CM.			
08/17	2079	60.5	13.3	5.7	3.34	1.42
08/24	2906	280.5	9.8	6.0	0.68	0.52
08/31	3432	1157.0	22.3	15.4	1.16	0.18
09/07	5254	233.0	47.5	23.3	1.59	0.43
09/14	6301	1212.5	56.7	29.2	1.49	0.31
09/21	6891	168.3	80.8	42.6	2.29	0.49
09/28	8531	953.4	85.9	53.5	2.45	0.54
10/05	8890	1045.9	107.4	49.6	2.76	0.54
10/12	9042	1036.7	111.0	52.6	3.42	1.67
10/19	10624	2282.2	138.6	46.1	3.05	1.65
10/26	10983	813.5	133.7	47.4	2.31	0.83
11/02	11159	98.8	142.2	40.8	4.59	0.29

TABLE XIX

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG./HA.), HEIGHT OF APICAL MERISTEM (CM.), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL1CUT4

WEEK BEGINNING ON	DRY MATTER PRODUCTION MEAN	DRY MATTER PRODUCTION STANDARD DEVIATION	HEIGHT OF APICAL MERISTEM MEAN	HEIGHT OF APICAL MERISTEM STANDARD DEVIATION	STEM-LEAF RATIO MEAN	STEM-LEAF RATIO STANDARD DEVIATION
	KG./HA.		CM.			
09/07	1924	176.1	12.5	4.6	1.00	0.00
09/14	2130	389.0	8.7	4.9	0.91	0.45
09/21	1741	383.8	16.6	6.7	0.69	0.21
09/28	2430	631.4	19.2	9.3	0.50	0.02
10/05	2798	158.6	25.1	13.4	0.64	0.26
10/12	3732	185.1	33.5	30.3	0.80	0.21
10/19	3976	721.1	44.4	21.3	1.31	0.46
10/26	4179	126.3	42.6	24.9	1.57	0.25
11/02	3994	683.0	56.6	30.9	1.95	0.10

TABLE XX

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL2CUTO

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG/HA.		CM.			
07/11	297	56.0	1.1	0.3	1.00	0.00
07/18	678	108.5	4.2	2.0	0.20	0.03
07/25	2650	473.2	30.6	6.8	0.87	0.20
08/01	3442	410.2	43.7	16.4	1.50	0.54
08/08	5553	481.3	76.7	38.0	2.68	1.02
08/15	8512	311.3	134.0	26.3	2.74	1.37
08/22	13859	858.2	165.0	33.8	3.32	0.21
08/29	15701	1524.7	187.6	32.5	2.26	1.40
09/05	17997	302.7	190.2	56.9	4.23	0.33
09/12	18692	1454.4	206.7	50.5	5.33	0.59
09/19	18777	478.4	195.9	41.1	5.33	0.93

TABLE XXI

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL2CUT1

WEEK BEGINNING ON	DRY MATTER PRODUCTION MEAN	DRY MATTER PRODUCTION STANDARD DEVIATION	HEIGHT OF APICAL MERISTEM MEAN	HEIGHT OF APICAL MERISTEM STANDARD DEVIATION	STEM-LEAF RATIO MEAN	STEM-LEAF RATIO STANDARD DEVIATION
	KG/HA.		CM.			
08/08	1019	209.0	9.8	6.8	1.01	0.20
08/15	1666	226.5	8.0	7.3	0.59	0.02
08/22	3187	291.5	25.2	14.2	0.89	0.09
08/29	4780	620.6	57.3	19.1	1.24	0.20
09/05	5945	71.8	71.6	32.9	1.48	0.40
09/12	7266	320.4	92.9	43.4	1.84	0.24
09/19	7769	618.8	123.4	46.9	2.30	0.06
09/26	9158	1721.6	137.2	65.4	2.90	0.16
10/03	10543	716.5	154.7	65.6	3.41	0.10
10/10	10724	1728.4	170.6	51.0	5.77	1.84
10/17	11333	459.8	172.3	43.3	4.06	0.28
10/24	11053	696.8	173.3	35.4	4.87	0.79

TABLE XXII

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL2CUT2

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG/HA.		CM.			
08/29	1445	324.9	9.3	5.7	1.00	0.00
09/05	1882	209.5	12.9	6.4	0.55	0.41
09/12	2121	540.5	15.2	7.4	0.47	0.08
09/19	1986	80.8	33.2	20.1	0.73	0.33
09/26	2649	1104.1	49.0	22.7	0.98	0.10
10/03	3629	352.2	70.8	33.9	1.62	0.24
10/10	3725	406.3	75.6	37.5	1.92	0.07
10/17	3540	192.1	85.8	46.7	2.69	0.37
10/24	4880	249.0	95.7	27.1	2.46	0.14
10/31	5102	277.6	89.7	41.9	2.52	0.64

TABLE XXIII

MEANS AND STANDARD DEVIATIONS OF CUMULATIVE DRY MATTER PRODUCTION (KG/HA), HEIGHT OF APICAL MERISTEM (CM), AND STEM-LEAF RATIOS (DRY MATTER BASIS) FOR TREATMENT PL2CUT3

WEEK BEGINNING ON	DRY MATTER PRODUCTION		HEIGHT OF APICAL MERISTEM		STEM-LEAF RATIO	
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	KG/HA.		CM.			
10/03	1355	54.7	11.6	5.8	1.00	0.00
10/10	1373	169.9	11.2	5.3	0.83	0.28
10/17	1345	239.7	8.7	6.2	1.33	0.57
10/24	1411	168.5	11.1	6.3	0.36	0.23
10/31	1574	272.8	10.6	6.1	0.66	0.28